FEDERAL UNIVERSITY OF SANTA MARIA
HEALTH SCIENCES CENTER
POSTGRADUATE PROGRAM IN SCIENCES
DENTAL

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DO POLYWAVE LEDS INCREASE THE DEGREE OF CONVERSION IN RESTORATIVE COMPOSITES? A SYSTEMATIC REVIEW

Santa Maria, RS
2023

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Dissertation presented to the Graduate Program in Dental Sciences, Federal University of Santa Maria (UFSM, RS) as a partial requirement to obtain the title of **Master in Dental Sciences with emphasis on Dental Materials**.

Orientador: Prof. Dr. Fabio Zovico Maxnuck Soares

Santa Maria, RS

2023

Corrêa, Amanda Luiza
DO POLYWAVE LEDS INCREASE THE DEGREE OF CONVERSION IN RESTORATIVE COMPOSITES? A SYSTEMATIC REVIEW / Amanda Luiza Corrêa.- 2023.
54 p.; 30 cm

Orientador: Fabio Zovico Maxnuck Soares
Coorientador: Luciano de Souza Gonçalves
Dissertação (mestrado) - Universidade Federal de Santa Maria, Centro de Ciências da Saúde, Programa de Pós Graduação em Ciências Odontológicas, RS, 2023

1. Composite resin 2. Degree of conversion 3. Photoactivation 4. Cure I. Zovico Maxnuck Soares, Fabio II. de Souza Gonçalves, Luciano III. Título.

Sistema de geração automática de ficha catalográfica da UFSM. Dados fornecidos pelo autor(a). Sob supervisão da Direção da Divisão de Processos Técnicos da Biblioteca Central. Bibliotecária responsável Paula Schoenfeldt Patta CRB 10/1728.

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Approved on December 14, 2023:

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Santa Maria, RS
2023

SPECIAL THANKS

I am grateful to God for guiding me on his path of light and love, for having graced me with life and for protecting me during the thousands of kilometers traveled in the last two years. I am also grateful for your health and willpower to overcome obstacles and pursue my dreams.

To my parents, Taís and Leandro, for giving me autonomy, for teaching me to never give up and for showing that with a lot of effort we can achieve everything we want. I am grateful for all the sacrifices and opportunities you gave me so that I could get to where I am today. You are examples of love, resistance and struggle. Love you.

I thank André, my best friend and life partner, without you I wouldn't be able to do this. Thank you for your patience and for always being by my side.

To Pedrita, my confidant and canine companion, thank you for all the love and affection.

To my advisor, Fabio Zovico Maxnuc Soares, who has been my biggest professional inspiration since graduation. I thank you for the opportunity, patience and for all the teachings you provided me.

To Professor Luciano de Souza Gonçalves, I thank you for all your support, encouragement and teachings during this period. His help was essential throughout these almost two years.

To Professor Anelise Montagner for her willingness to participate as a panel in this study in the qualification process, offering her vast knowledge and her considerations. Thank you again, it was and is an honor for me.

To the Federal University of Santa Maria, which welcomed me in 2016 and allowed me to grow both as a professional and as a human being. I believe that quality public education can transform lives and make dreams come true.

RESUMO

LEDS POLYWAVE AUMENTAM O GRAU DE CONVERSÃO EM COMPÓSITOS RESTAURADORES? UMA REVISÃO SISTEMÁTICA

AUTORA: Amanda Luiza Corrêa
ORIENTADOR: Fabio Zovico Maxnuck Soares

Fotoiniciadores alternativos vem sendo desenvolvidos com intuito produzir compósitos restauradores com qualidades ópticas superiores sem prejuízo das propriedades mecânicas. Contudo, estes compósitos exigem uma fonte de luz com espectro de emissão ampliado, resultando nas fontes de luz emitida por diodo (LED) polywave, com picos de emissão em mais de um comprimento de onda. Diversos estudos in-vitro avaliaram o grau de conversão (GC) produzidos por estes LEDs comparados aos tradicionais, em diferentes compósitos restauradores para verificar a eficiência da polimerização gerada. O objetivo nesse estudo foi revisar sistematicamente a literatura para estudos laboratoriais que avaliaram a influência dos LEDs no GC de compósitos resinosos restauradores. A busca foi realizada nas bases de dados eletrônicas PubMed, Scopus e Web of Science a partir da estratégia criada pela combinação de termos específicos (MeSH) e livres, sem restrição de data ou idioma com base na questão de pesquisa: LEDs polywave aumentam o grau de conversão em compósitos restauradores? Dois revisores, de forma independente selecionaram os estudos seguindo os critérios de inclusão: avaliação do GC de forma direta, comparando grupos de fontes de luz monowave e polywave. Estudos que não apresentaram média e desvio padrão em valores numéricos para o grau de conversão, avaliaram materiais de presa química ou dual foram excluídos. De 44 estudos potencialmente elegíveis 21 foram selecionados para leitura integral. Destes 16 foram incluídos e através da busca em suas referências mais 5 estudos foram incluídos, totalizando 21 artigos na revisão sistemática e meta-análise. Os revisores que selecionaram os estudos, extraíram dados pertinentes como: autor, ano, país, material avaliado, fonte de luz utilizada, exposição radiante, profundidade, armazenamento e valores de GC. A meta-análise foi realizada através do Z test com efeitos aleatórios e nível de significância de 5%, comparando os dados de GC (média e desvio padrão), gerados por LEDs polywave e monowave. A análise do risco de viés foi calculada por critério adaptado de uma revisão sistemática previa, categorizando os estudo primários em alto, médio ou baixo. A meta-análise apontou diferença significativa positiva em favor dos LEDs polywave (Z=3,74; p=0,0002), com alta heterogeneidade I2=92%. A maioria dos estudos incluídos (18) apresentou alto risco de viés. Conclui-se que os dados in vitro atualmente disponíveis permitem inferir que LEDs polywave promovem maior GC em resinas compostas comparado a LEDs monowave.

Palavras-chave: Resina composta. Grau de conversão. Fotoativação. Cura.

ABSTRACT

DO POLYWAVE LEDS INCREASE THE DEGREE OF CONVERSION IN RESTORATIVE COMPOSITES? A SYSTEMATIC REVIEW

AUTHOR: Amanda Luiza Corrêa
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Alternative photoinitiators have been developed with the aim of producing restorative composites with superior optical qualities without compromising mechanical properties. However, composites with these photoinitiators require a light source with an extended emission spectrum, with emission peaks at more than one wavelength, resulting in polywave emitted diode light (LEDs) sources. Several in-vitro studies evaluated the degree of conversion (CD) produced by these LEDs compared to traditional ones, in different restorative composites to verify the efficiency of the generated polymerization. The objective of this study was to systematically review the literature for laboratory studies that evaluated the influence of LEDs on the DC of restorative resin composites. The search was carried out in the PubMed, Scopus and Web of Science electronic databases based on the strategy created by combining specific (MeSH) and free terms, without date or language restriction based on the research question: polywave LEDs increase the degree of conversion into restorative composites? Two reviewers independently selected the studies following the inclusion criteria: direct assessment of DC, comparing groups of monowave and polywave light sources. Studies that did not show mean and standard deviation in numeric values for the degree of conversion, evaluated chemical or dual setting materials were excluded. Of 44 eligible environmental studies 21 were selected for full reading. Of these, 16 were included and, through searching their references, 5 more studies were included, totaling 21 articles in the systematic review and meta-analysis. Two reviewers selected the studies and extracted pertinent data such as: author, year, country, material evaluated, light source used, radiant exposure, depth, storage and DC values. A meta-analysis was performed using the Z test with random effects and a significance level of 5%, comparing DC data (mean and standard deviation) generated by polywave and monowave LEDs. The risk of bias analysis was calculated using specifications adapted from a previous systematic review, categorizing primary studies as high, medium or low. The meta-analysis showed a significant positive difference in favor of polywave LEDs ($Z=3.74$; $p=0.0002$), with high heterogeneity $I2=92\%$. Most of the included studies (18) presented a high risk to life. It is concluded that the currently available in vitro data allows us to infer that polywave LEDs promote greater DC compared to monowave LEDs.

Keywords: Composite resin. Degree of conversion. Photoactivation. Cure.

SUMMARY

1. INTRODUCTION

Resin-based restorative materials are increasingly chosen for the restoration of anterior and posterior teeth, due to their aesthetic properties, conservative approach and the possibility of adhesion and being repaired over time. (WORTHINGTON et al., 2021) Adequate polymerization is essential for clinical use, as it results in better mechanical and aesthetic properties. (AGUIAR et al., 2011) In general, the degree of conversion (DC) of photoactivated composites varies between 45% and 75%, depending on the composition of the material (GAJEWSKI et al., 2012), mainly on the type of photoinitiator and the light source (AGUIAR et al., 2011)

Camphorquinone (CQ) is widely used as a photoinitiator in resin-based restorative materials. To increase its reactivity, CQ is used together with a tertiary amine as a co-initiator, resulting in a photoinitiator system (ILIE & RICKEL, 2008) (CUNHA BRANDT et al., 2010) (SHIMOKAWA et al., 2017). In this process, free radicals are formed, resulting in a chain reaction of radical propagation, which is influenced by the number of reactants and the incident light (LEE et al., 2012). However, camphoroquinone has some disadvantages, such as its strong and bright yellow color, which influences the final appearance of the polymerized material, (ILIE; HICKEL, 2008a) this limits its use mainly in light and translucent shades of composite resin (SHIMOKAWA et al., 2017). In addition, unreacted CQ/amine systems could also affect the final appearance of the restoration, by degrading color and esthetic properties (LEE et al., 2012).

Alternative photoinitiators such as 2,2-dimethoxy [1,2] diphenylethanone (DMBZ), phenylpropanedione (PPD), phosphine oxides, and trimethylbenzoyl-diphenylphosphine oxide (TPO)(LEE et al., 2012; SANTINI et al., 2012) have been introduced to circumvent the yellowing effect of QC/amine systems and can be used alone or in combination as a QC co-initiator (BRANDT et al., 2013) . These photoinitiators, considered as Norrish type I photoinitiator systems, have a lower yellowing index, which is explained by their lighter composition and their reactive potential(SCHROEDER; VALLO, 2007) . They are based on the splitting of a molecule into two free radical intermediates capable of initiating the polymerization process(MOSZNER; SALZ, 2007), and therefore, unlike camphorquinone, they do not require a co-initiator(SCHROEDER; VALLO, 2007). Despite their greater reactivity, type I photoinitiator systems require shorter wavelengths than the traditional camphorquinone spectrum characteristic (approximately 460nm)(SANTINI, 2010; SANTINI et al., 2012).

The addition of photoinitiators with different light absorption spectra required the development of light-curing devices that provide multiple wavelength peaks(SANTINI; MCGUINNESS; MD NOR, 2014). Polywave (dual/multi-peak) light-emitting diodes (LEDs) emit light at different wavelengths, including the blue (420-496 nm) and violet (380-420 nm) spectra(PRICE et al., 2010b). These different wavelengths are generated by the distribution of several chips in the device, each of which emits a specific wavelength from a broad spectrum of visible light, thus improving polymerization efficiency. Since Polywave LEDs guarantee a high irradiance to sensitize traditional and alternative photoinitiators, the question arises as to the real effectiveness of these light-curing units in achieving a high degree of conversion in resin-based restorative composites, all containing different photoinitiators. However, issues of irradiance and wavelength that are not evenly distributed by the light tip (PRICE et al., 2010a), which reduces the depth of cure(LEPRINCE et al., 2011) affect light curing and material properties.

Once the degree of conversion and the physical and chemical properties of resin composites depend on the total energy and radiation exposure (HADIS et al., 2011). Therefore, considering the various LED units commercially available, it is of most importance to summarize and quantitatively analyze the evidence for the superiority of polywave LED units in terms of the degree of conversion of resin-based materials. The aim of this study was therefore to systematically review the literature on the influence of monowave and polywave LEDs on the degree of conversion of resin-based materials.

2 ARTICLE - Do polywave LEDs increase the degree of conversion in restorative composites? A systematic review.

This article will be submitted to the Journal of Applied Oral Science, ISSN: 1678-7757, Impact factor = 1.797; Qualis A2. The publication standards are described in Appendix A.

Do polywave LEDs increase the degree of conversion in restorative composites? A systematic review.

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Do polywave LEDs increase the degree of conversion in restorative composites? A systematic review

Abstract

Introduction: alternative photoinitiators have been developed with the aim of producing restorative composites with superior optical qualities without compromising mechanical properties. However, composites with these photoinitiators require a light source with an extended emission spectrum, with emission peaks at more than one wavelength, resulting in polywave emitted diode light (LEDs) sources. Several in-vitro studies evaluated the degree of conversion (DC) produced by these LEDs compared to traditional ones, in different restorative composites to verify the efficiency of the generated polymerization.
Objective: systematically review the literature for laboratory studies that evaluated the influence of LEDs on the DC of restorative resin composites.
Methodology: the search was carried out in electronic databases based on the research question: polywave LEDs increase the degree of conversion into restorative composites? Two reviewers independently selected the studies following the inclusion criteria: direct assessment of DC, comparing groups of monowave and polywave light sources. Of 44 eligible environmental studies 21 were selected for full reading. Of these, 16 were included and, through searching their references, 5 more studies, totaling 21 articles in this study. Two reviewers selected the studies and extracted pertinent data. A meta-analysis was performed using the Z test with random effects and a significance level of 5%, comparing GC data (mean and standard deviation) generated by polywave and monowave LEDs. The risk of bias analysis was calculated using specifications adapted from a previous systematic review, categorizing primary studies as high, medium or low, 18 studies presented a high risk to bias.
Results: the meta-analysis showed a significant positive difference in favor of polywave LEDs (Z=3.74; p=0.0002), with high heterogeneity I2=92%.
Conclusion: it is concluded that the currently available in vitro data allow us to conclude that polywave LEDs promote a higher level of DC compared to monowave LEDs.

Keywords: Composite resins. Curing Lights, Dental. Photoinitiators, Dental.

1. Introduction

Resin-based restorative materials are increasingly chosen for the restoration of anterior and posterior teeth, due to their aesthetic properties, conservative approach due to the possibility of adhesion and being repaired over time.[1] Proper polymerization is fundamental for clinical use, as it results in better mechanical and aesthetic properties.[2] In general, the degree of conversion (DC) of photoactivated composites varies between 45% and 75%, depending on the composition of the material [3], especially the type of photoinitiator and the light source[2].

Camphorquinone (CQ) is widely used as a photoinitiator in resin-based restorative materials. To increase its reactivity, CQ is used together with a tertiary amine as a co-initiator, resulting in a photoinitiator system [4–6]. In this process, free radicals are formed, resulting in a chain reaction of radical propagation, which is influenced by the number of reactants and the incident light.[7] However, camphoroquinone has some disadvantages, such as its strong and bright yellow color, which influences the final appearance of the polymerized material,[4] this limits its use mainly in light and translucent shades of composite resin[6]. In addition, unreacted CQ/amine systems could also affect the final appearance of the restoration, by degrading color and esthetic properties[7].

Alternative photoinitiators such as 2,2-dimethoxy [1,2] diphenylethanone (DMBZ), phenylpropanedione (PPD), phosphine oxides, and trimethylbenzoyl-diphenylphosphine oxide (TPO)[7,8] have been introduced to circumvent the yellowing effect of QC/amine systems, and can be used alone or in combination as a QC co-initiator [9] . These photoinitiators, considered as Norrish type I photoinitiator systems, have a lower yellowing index, which is explained by their lighter composition and their reactive potential[10] . They are based on the splitting of a molecule into two free radical intermediates capable of initiating the polymerization process[11], and therefore, unlike camphorquinone, they do not require a co-initiator[10]. Despite their greater reactivity, type I photoinitiator systems require shorter wavelengths than the traditional camphorquinone spectrum characteristic (approximately 460nm)[8,12].

The addition of photoinitiators with different light absorption spectra required the development of light-curing devices that provide multiple wavelength peaks[13]. Polywave (dual/multi-peak) light-emitting diodes (LEDs) emit light at different wavelengths, including the blue (420-496 nm) and violet (380-420 nm) spectra[14.] These different wavelengths are generated by the distribution of several chips in the device, each of which emits a specific wavelength from a broad spectrum of visible light, thus improving polymerization efficiency. Since Polywave LEDs guarantee a high irradiance to sensitize traditional and alternative photoinitiators, the question arises as to the real effectiveness of these light-curing units in achieving a high degree of conversion in resin-based restorative composites, all containing different photoinitiators. However, issues of irradiance and wavelength that are not evenly distributed by the light tip [15], which reduces the depth of cure[16] affect light curing and material properties.

Once the degree of conversion and the physical and chemical properties of resin composites depend on the total energy and radiation exposure [17]. Therefore, considering the various LED units commercially available, it is of most importance to summarize and quantitatively analyze the evidence for the superiority of polywave LED units in terms of the degree of conversion of resin-based materials. The aim of this study was therefore to systematically review the literature on the influence of monowave and polywave LEDs on the degree of conversion of resin-based materials.

2. Material and methods

This systematic review was conducted according to the Cochrane Handbook[18] and reported according the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analyses)[19]. The following research question was formulated to examine the literature and outline the search strategy "Do polywave LEDs increase the degree of conversion of resin-based restorative materials”. The Population, Intervention, Comparison, Outcome (PICO) scheme was applied as follows: Population - resin-based restorative materials, Intervention - polywave LEDs, Comparison - monowave LEDs, and Outcome - degree of conversion.

2.1 Sources and search strategy

The online databases considered were PubMed/MEDLINE, SCOPUS and ISI Web of Science (Table 1). The search was performed without any date or language restrictions up to September 30th, 2023. The search strategy designed for the PubMed/MEDLINE database was developed by combining controlled terms (Mesh terms) and free terms (All fields). For SCOPUS and ISI Web of Science databases, free search terms were used to find PICO. Manual searches were performed using the reference lists of included studies.

2.2 Selection, inclusion and exclusion criteria

Laboratory studies were selected that examined the degree of conversion (outcome) of resin-based restorative materials (population) after curing with polywave LED devices (intervention) compared to monowave LED devices (control).

The titles and abstracts of potential studies were independently screened by two authors (A.L.C. and G.M.) and selected by consensus using the following inclusion criteria: 1) papers that evaluated the degree of conversion of resin-based materials using polywave LED; 2) presence of a control group (monowave LED); 3) evaluation of the degree of conversion by direct measurement (Fourier-transform infrared spectroscopy or micro-Raman spectroscopy). Final inclusion was done after the full-text reading of the eligible studies by both reviewers (A.L.C. and G.M.), taking into account the exclusion criteria: 1) missing or incomplete description of the method used to evaluate the degree of conversion; 2) light-curing protocol not described of incompletely described (unit, irradiance, time); 3) missing numerical data on the degree of conversion (mean and standard deviation). Disagreements regarding the eligibility criteria were resolved through discussion and consensus by a third reviewer (F.Z.M.S.).

2.3 Data extraction

Relevant data were extracted by two authors (A.L.C. and F.ZMS) using a standardized form in Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA). For each paper, the following data were systematically extracted: year of publication, first author's country, degree of conversion method, number of specimens per experimental group, LED curing units considered, energy density, resin-based material evaluated, depth, storage, and the degree of conversion values (mean and standard deviations in %). For studies that did not clearly provided data, authors were contacted by e-mail 3 times at 2-week intervals. If no data were provided, the study was excluded from the systematic review.

2.4 Risk of bias assessment

The risk of bias was assessed using the criteria described in a previous systematic review[20] and adapted for the present review, taking into account the following: random order in the preparation of the specimens, sample size calculation, equal number of specimens in the experimental groups, a single operator involved in the preparation of the specimens, use of light-curing units according to the instructions of the manufacturer of the resin-based materials (time and irradiance), and blinding of the responsible operator for analyzing the outcome. For each item that could be identified, the study received a 'YES', and for any missing information, 'NO' was assigned. The risk of bias was graded according to the sum of the number of items that scored 'YES' as follows: 1 and 2 = high risk of bias; 3 and 4 = medium risk of bias; 5 and 6 = low risk of bias.

2.5 Data analysis

For the meta-analyses, the pooled effect estimates were obtained by comparing the degree of conversion values (mean and standard deviations in %) of monowave and polywave LED units, considering the resin-based material as composite resin and adhesive system, separately. Subgroup analyses for composite resin were performed according to DC measurement specimen surface - top and bottom. For studies that evaluated more than one resin-based composite, the DC means (standard deviations) were combined into one mean (standard deviation) using a predefined formula (Cochrane Statistical Guidelines) [18]. Random effects comparative meta-analysis was performed, calculating standardized mean differences with a 95% confidence interval. Heterogeneity was quantified using the Cochran Q test and I^2 (>50% indicates high heterogeneity) [18]. All analyzis were performed using RevMan (Review Manager version 5.3; Cochrane Collaboration, London, UK). Forest plots were created to illustrate the meta-analysis.

3. Results

3.1. Study selection

A total of 103 potentially relevant studies were identified in online databases. After removing duplicates, 49 studies were screened, numeric data (mean or standard deviation). Sixteen studies were included based on the online search and five studies was found in the reference list. Thus, 21 studies were included in the systematic review and meta-analysis. Figure 1 shows the flowchart summarizing the study selection process.

3.2. Characteristics of Included Studies

Table 2 describes a detailed summary of the included studies. These 21 studies were published between 2008 and 2022 and were conducted by researchers from eight countries, including 11 studies from Brazil [2,5,9,21–28] All studies were published in English. Four commercially available polywave LED devices were considered, with Bluphase G2 being the most evaluated.[8,13,22,24,29–31] Two studies included a prototype or custom-designed polywave LED device.[6,32] Ten commercially available monowave LED devices were considered as controls, and Bluephase being the most commonly used.[2,8,13,29,30,32] One custom-designed monowave LED device was used as a control group. [6] Sixteen studies evaluated the DC of composite resins, including 6 studies using experimental composite resins [5,9,21,22,27,29] and 3 studies considered bulk-fill composite resins. [25,31,33] Five studies evaluated the DC of adhesive systems, including orthodontic adhesive systems [13,23,24] and experimental systems [26,28], one study investigated two commercially available adhesive systems and two experimental materials based on commercial systems but with Lucirin TPO as the initiator.[32] However, these experimental adhesives were light-cured using only polywave LED devices, without a monowave LED device as a control. Therefore, only the data on the commercial adhesives were considered in the meta-analysis.

Fourrier transform infrared spectroscopy was the most common method used to access the degree of conversion (16 studies) [2,5–7,21–28,31–34] and micro-Raman spectroscopy used in four studies [8,13,29,30]and one mid-infrared spectroscopy[9].

3.3. Meta-analysis

Two overall meta-analyses were conducted according to resin-based material, considering composite resin, further stratified by top or bottom DC evaluation, and adhesive systems considered separately. According to the overall meta-analysis for composite resins (Figure 2), polywave LED devices promoted higher DC compared to monowave LED devices (control) Z = 3.74; p = 0.0002). Throughout the meta-analysis, heterogeneity was found to be 92%. The subgroup meta-analysis that considered the degree of conversion measurement of the specimen surface as a predictor of depth of cure found no evidence that the effect of the polywave or monowave LED devices on the top surface (figure 3) of the specimens (Z = 1.37; p=0.17; heterogeneity of 85%) or the bottom surface (figure 4) of the specimens (Z = 1.93; p=0.05; heterogeneity of 86%). The overall meta-analysis considering adhesive systems (figure 5) showed no statistically significant difference comparing polywave and monowave LED devices (Z = 1.34; p = 0.18; heterogeneity of 63%).

3.4. Assessment of risk of bias

All included studies in the systematic review scored between medium and high risk of bias (Table 3). From the 21 studies, 18 scored high[4–9,13,21–24,26–29,31,33,34] and 3 scored medium risk. [2,25,30] The items that most frequently received “no” in the analysis were: single operator making the specimens, operator blinded to experimental condition during DC evaluation and sample size calculation.

4. **Discussion**

This meta-analysis examined in vitro data obtained using polywave versus monowave LED devices on the degree of conversion of resin-based materials. The pooled data statistically confirmed the research question that polywave LED devices increase the degree of conversion of composite resins, including conventional, bulk-fill and experimental resins. The issues regarding the non-homogeneous wavelengths of polywave LED devices, which can lead to irregular irradiance and poor polymerization [22] are not consistent with the results of the overall meta-analysis.

The degree of conversion of composite resins depends mainly on the LED device, monomer, initiator composition, resulting in a polymer network [7]. The size and amount of the filler also affect the degree of conversion through translucency of the material. Large amounts of filler particles combined with high molecular weight monomers could have a negative effect on the light transmission of the composite[25]. Included studies considered 17 commercially available conventional composite resins, three commercially available bulk-fill resins and 6 experimental composite resins, containing camphorquinone or alternative photoinitiators. The overall meta-analysis was performed considering only the type of LED device, irrespective of the type of composite resin. The exact composition of each composite resin, including the type of photoinitiator, was not clearly described in the primary studies and frequently is not reported by the manufacturers. For this reason, subgroup analyses that take these factors into account could not be performed.

However, five studies investigated adhesive systems, i.e. materials that differ significantly in composition from composite resins, particularly with regard to the presence of pigments and filler particles[13,23,26,28,32]. For this reason, a global meta-analysis was carried out using only data from studies that compared the degree of conversion of adhesive systems light-cured with mono- or polywave LED devices[2,5–9,21,22,24,25,27,29–31,33,34]. No significant effect of LED device on degree of conversion of adhesive systems was found in the meta-analysis. It should be noted that two of the included studies evaluated the degree of conversion of the experimental adhesive systems. In addition, the degree of conversion of orthodontic adhesive systems was also evaluated in the included studies [13,23].

The most common photoinitiator in the included studies was camphorquinone, a yellowish and less reactive molecule that forms a traditionally used initiator complex in combination with amine[4,5,22]. This molecule is sensitized by a visible light spectrum between 400 and 500 nm with an excitation peak around 470 nm, compatible with monowave LED devices [4]. Alternative photoinitiators derived from acylphosphine oxides (MAPO and BAPO) and alpha-diketones (PPD) have been identified[9] . These alternative photoinitiators have been developed to improve the properties of restorative composites, acting alone or synergistically as co-initiators[4,9,10]. The latter has a mechanism of free radical generation by photolysis capable of initiating the polymerization reaction or even acting as a co-initiator because it has the same diketone group as camphorquinone [5], thus reducing the amount of camphorquinone, and consequently the yellowing effect, maintaining the same degree of conversion, through a slower polymerization reaction, and generating less polymerization stress and guaranteeing the preservation of the tooth/restoration bond[21]. The alternative photoinitiator systems, classified as Norrish Type I, are characterized by unimolecular bond breaking after irradiation [9], which promotes the clevage of a molecule into two free radical intermediates, resulting in higher reactivity[11]. Nevertheless, they require light with wavelengths in the light absorption spectrum that are shifted more to the UV region, below 420 nm, which does not match the emission range of monowave LED devices, making them incompatible[12] and potentially negatively affecting the mechanical properties, biocompatibility, and degree of conversion of restorative composites[30] .

Polywave LEDs also emit a broad spectrum of different length and color waves [23,30]. Violet light with lower peaks is necessary to sensitize the alternative initiators; however, this low wavelength is less prone to effectively penetrate deep into the composite[25]. This limitation is explained by the Rayleigh-wave dispersion theory, in which light with short wavelengths (380 - 430nm) is reflected by the filler particles present in the material and is not transmitted through the restoration body[7,25,34]. However, the pooled effect of polywave LED devices was not significant when comparing the degree of conversion according to the measured surface of the specimen - top and bottom. In the analysis, only studies that included the comparison of the degree of conversion on the both top and bottom surfaces were considered. Therefore, only a few studies were included in the subgroup analysis, so the influence of the LED devices could not be detected. It is important to consider that in these studies the thickness of the specimens varied between 2 and 4 mm.

The evaluation of the degree of conversion by direct methods has usually been performed using Fourier Transform Infrared Spectroscopy (FTIR) [2,5–7,21–28,31–34], which can identify molecular structures in the composition of materials based on energy absorption in the infrared region. Existing biochemical bonds are detected based on the degree of their molecular rotation and the type of movement[35]. Micro-Raman spectroscopy, which was used in four studies [8,13,29,30] evaluates the degree of conversion through molecular attraction, polarization, and light scattering, where incident photons from the infrared laser source interact with a molecular configuration, resulting in the scattering of light[36]. Only one study has evaluated the degree of conversion by mid-IR spectroscopy[9], which is very similar to micro-Raman and is based on the vibration of chemical bonds but is summarized in a dipole moment that is present only in diatomic or more complex molecules[36].

The energy emitted by LED devices with more than one peak, delivers less energy in the blue region in comparison with monowave LEDs devices[6]. Among the included studies, the energy delivered by LED devices ranged from 6.5 J to 36 J, with similar energies between experimental and control groups[4–7,9,12,21–26,34]. However, in some studies, the same photoactivation time was used with different amounts of emitted energy, with monowave LED devices providing a higher output energy[2,28–30].

Of the 21 studies, 14 were published in the last decade [6,9,13,22–28,30,31,33,34]. This can be explained by the increase in the aesthetic trend in dentistry, the presence of teeth undergoing bleaching and ceramic orthodontic brackets require lighter resin materials that maintain adequate polymerization[22,30] . Another trend in the recent development of light curing devices is the reduction of curing time [6,22]. Evaluating the degree of conversion with shortened times using newer light curing devices is an issue currently being addressed [8,16].

Regarding the risk of bias, of 21 studies, 18 scored high [4–9,13,21–24,26–29,31,33,34] and 3 scored medium risk. [2,25,30]. The items that most frequently received “no” in the analysis were: single operator making the specimens, operator blinded to experimental condition during DC evaluation and sample size calculation. The most frequent items scored as "No" were related to a single operator involved in specimens preparation and sample size calculation, compromising test standardization. In general, laboratory studies lack accuracy in describing methodology, particularly in providing information that affect directly the risk of bias. The fact that most studies were classified with a high risk of bias can be considered a weakness of this systematic review. In addition, a high heterogeneity found throughout in the overall meta-analysis. Heterogeneity was the reason given for not performing the meta-analysis in a recent systematic review. However, high heterogeneity is common in meta-analyzes of laboratory studies[37,38], possibly influenced by the analysis of the outcome (degree of conversion) with different methods, variability in the methodology used to prepare the specimens, and the incomplete description of the methodology as previously reported. Therefore, the overall and the subgroup meta-analysis were carried out using a random-effects model, taking into account that the true effect could vary from study to study because of the heterogeneity [39] and assuming that the heterogeneity is completely random[40].

5. Conclusion

Through meta-analysis, it can be concluded that polywave LED devices produce a higher degree of conversion of composite resins compared to monowave LED devices. The use of mono or polywave LED devices results in similar degree of conversion of adhesive systems.

6. Funding sources and conflicts of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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TABLES AND ILLUSTRATIONS

Figure 1: Flowchart referring to the process of inclusion studies

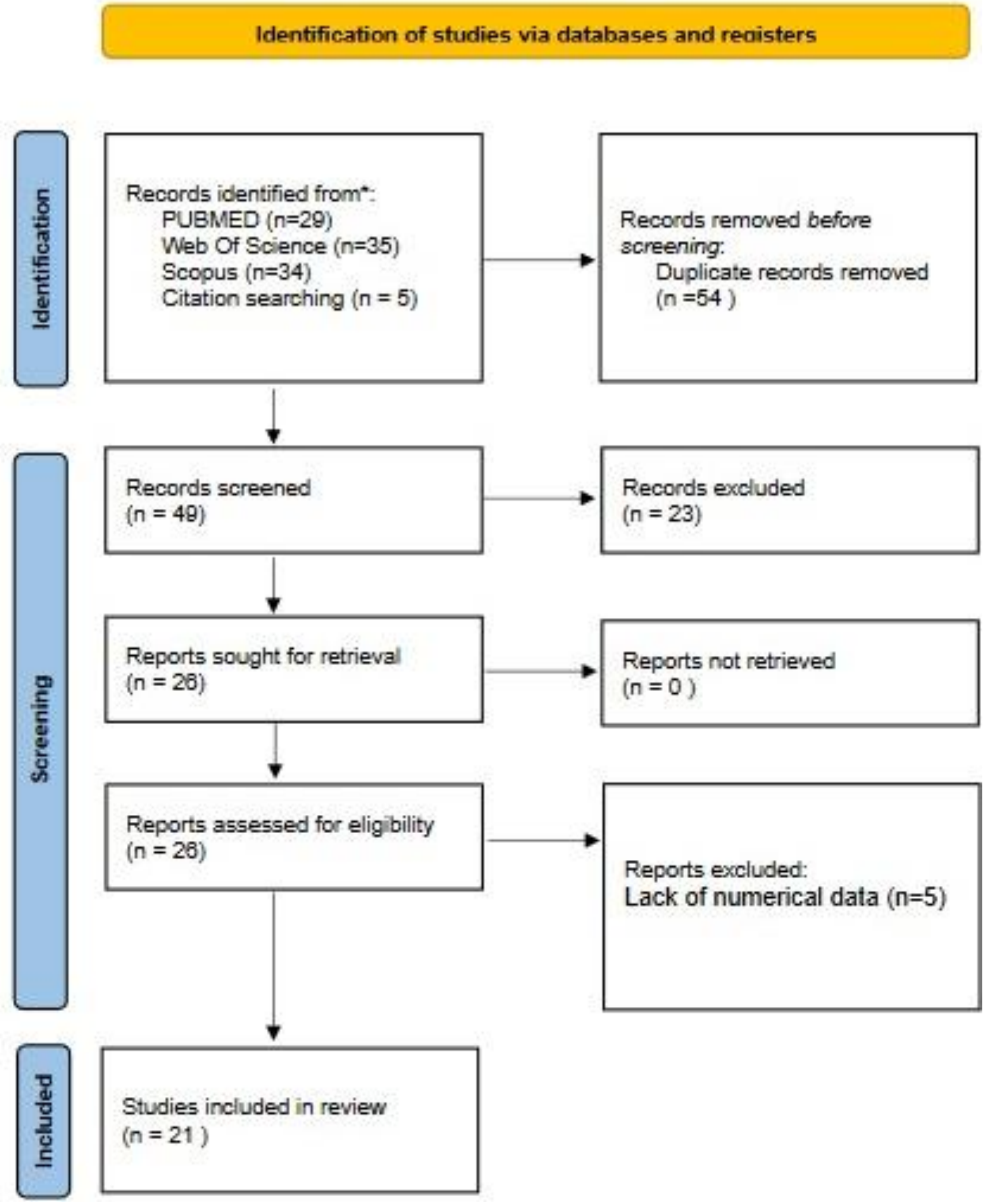

Figure 2: DC measurement global meta-analysis for composite resins

Study or Subgroup	Polywave Mean	Polywave SD	Polywave Total	Monowave Mean	Monowave SD	Monowave Total	Weight	Std. Mean Difference IV, Random, 95% CI
Aguiar et al. 2011	77.01	1.25	12	76.96	0.53	12	6.0%	0.05 [-0.75, 0.85]
Al Nahedh et al. 2022	58.23	10.4	240	55.22	11.02	240	7.2%	0.28 [0.10, 0.46]
Brandt 2013	71.73	2.85	12	66.73	1.34	12	5.3%	2.17 [1.12, 3.21]
Brandt et al. 2010	62.83	1.46	30	61.77	1.35	30	6.6%	0.74 [0.22, 1.27]
Brandt et al. 2011	51.97	3.02	9	48.63	2.76	9	5.4%	1.10 [0.09, 2.11]
Cardoso et al. 2017	57.68	4.15	42	5.02	8.5	42	4.7%	7.80 [6.52, 9.08]
Contreras et al. 2021	53.12	6.96	15	55.71	6.03	15	6.2%	-0.39 [-1.11, 0.34]
Lee et al. 2012	58.78	9.61	50	54.85	12.9	50	6.9%	0.34 [-0.05, 0.74]
Lee et al. 2013	59.88	9.79	60	60.79	12.16	60	6.9%	-0.08 [-0.44, 0.28]
Lucey et al. 2014	73.18	13.49	48	73.2	13.55	24	6.7%	-0.00 [-0.49, 0.49]
Miletic, Santini 2012	83.7	4.4	30	75.42	4.93	30	6.5%	1.75 [1.15, 2.35]
Oliveira et al. 2016	83.2	4.96	30	75.83	3.56	30	6.5%	1.68 [1.09, 2.28]
Santini et al. 2012	64.8	6.47	30	59.47	9.11	15	6.4%	0.70 [0.07, 1.34]
Santos et al. 2018	40.78	12.6	10	40.13	12.6	10	5.8%	0.05 [-0.83, 0.93]
Shimokawa et al. 2017	70.49	3.71	40	70.01	3.73	40	6.8%	0.13 [-0.31, 0.57]
Siagian et al. 2020	51.37	11.79	15	48.81	14.61	15	6.2%	0.19 [-0.53, 0.91]
Total (95% CI)			**673**			**634**	**100.0%**	**0.90 [0.43, 1.37]**

Heterogeneity: Tau² = 0.80; Chi² = 199.52, df = 15 (P < 0.00001); I² = 92%
Test for overall effect: Z = 3.74 (P = 0.0002)

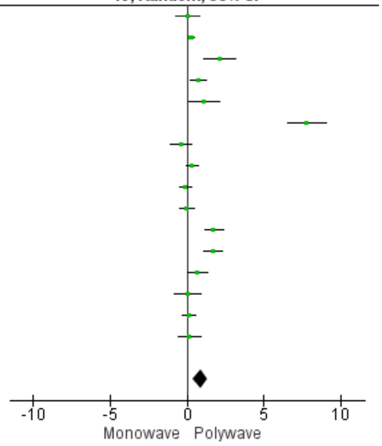

Figure 3: DC measurement subgroups meta-analysis for the top surface

Study or Subgroup	Polywave Mean	Polywave SD	Polywave Total	Monowave Mean	Monowave SD	Monowave Total	Weight	Std. Mean Difference IV, Random, 95% CI
Al Nahedh et al. 2022	61.52	7.26	90	58.55	9.52	90	23.6%	0.35 [0.05, 0.64]
Lee et al. 2012	64.84	5.39	25	64.46	6.58	25	20.8%	0.06 [-0.49, 0.62]
Lee et al. 2013	64.63	6.48	30	66.5	9.47	30	21.4%	-0.23 [-0.74, 0.28]
Lucey et al. 2014	77.24	14.52	24	77.74	14.89	12	19.1%	-0.03 [-0.73, 0.66]
Miletic, Santini 2012	86.96	2.92	15	79.49	2.65	15	15.1%	2.61 [1.60, 3.61]
Total (95% CI)			**184**			**172**	**100.0%**	**0.43 [-0.19, 1.06]**

Heterogeneity: Tau² = 0.40; Chi² = 25.95, df = 4 (P < 0.0001); I² = 85%
Test for overall effect: Z = 1.37 (P = 0.17)

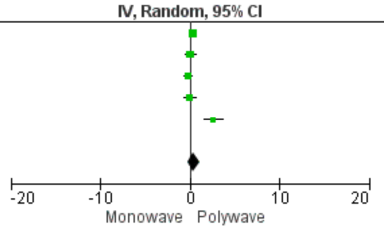

Figure 4: DC measurement subgroup meta-analysis for the bottom surface

Study or Subgroup	Polywave Mean	Polywave SD	Polywave Total	Monowave Mean	Monowave SD	Monowave Total	Weight	Std. Mean Difference IV, Random, 95% CI
Al Nahedh et al. 2022	53.16	12.36	90	49.79	13.43	90	23.5%	0.26 [-0.03, 0.55]
Lee et al. 2012	52.72	9.62	25	45.4	10.52	25	20.8%	0.71 [0.14, 1.29]
Lee et al. 2013	55.23	10.45	30	55.32	12.11	30	21.6%	-0.01 [-0.51, 0.50]
Lucey et al. 2014	69.1	11.25	24	69.58	11.24	12	19.4%	-0.04 [-0.73, 0.65]
Miletic, Santini 2012	80.46	2.99	15	71.34	2.82	15	14.7%	3.05 [1.96, 4.15]
Total (95% CI)			**184**			**172**	**100.0%**	**0.65 [-0.01, 1.31]**

Heterogeneity: Tau² = 0.46; Chi² = 28.47, df = 4 (P < 0.0001); I² = 86%
Test for overall effect: Z = 1.93 (P = 0.05)

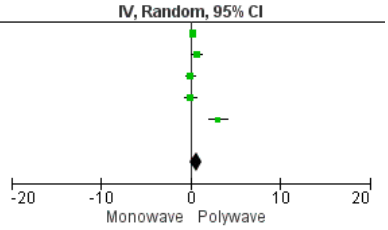

Figure 5: DC measurement meta-analysis for adhesive systems

Study or Subgroup	Polywave Mean	Polywave SD	Polywave Total	Monowave Mean	Monowave SD	Monowave Total	Weight	Std. Mean Difference IV, Random, 95% CI
Amato et al. 2016	74.35	9.86	10	73.25	9.83	10	14.5%	0.11 [-0.77, 0.98]
Boeira et al. 2021	73.7	4.53	18	57.07	29.44	18	18.7%	0.77 [0.09, 1.45]
Ilie, Hickel. 2008	76.21	9.54	96	69.97	6.15	48	27.5%	0.72 [0.37, 1.08]
Neto et al. 2022	59.37	15	30	61.58	16.74	30	23.3%	-0.14 [-0.64, 0.37]
Santini et al. 2014	55.58	8.1	18	56.87	9.33	9	16.0%	-0.15 [-0.95, 0.65]
Total (95% CI)			**172**			**115**	**100.0%**	**0.30 [-0.14, 0.75]**

Heterogeneity: Tau² = 0.15; Chi² = 10.86, df = 4 (P = 0.03); I² = 63%
Test for overall effect: Z = 1.34 (P = 0.18)

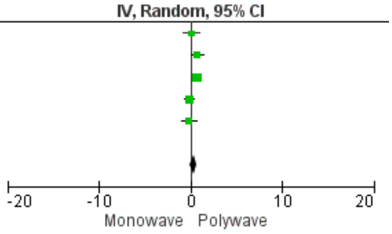

Table 1: source and search strategy

DATABASE: PUBMED	DATABASE: SCOPUS	DATABASE: ISI WEB OF SCIENCE
SEARCH STRATEGY	**SEARCH STRATEGY**	**SEARCH STRATEGY**
((((((((((((((curing lights, dental [MeSH Terms]) OR (curing lights, dental)) OR (curing light, dental)) OR (dental curing light)) OR (dental curing lights)) OR (LED dental curing lights)) OR (Light emitting diodes)) OR (Light curing unit*)) OR (Light curing)) OR (LED light curing unit)) OR (LED curing light)) AND ((((second generation LCU) OR (Second generation LED Curing Light*)) OR (Single peak LED)) OR (AND (((((Polywave LED) OR (UV LED)) OR (Broad spectrum LED curing light)) OR (Dual peak LED)) OR (AND ((((((((Composite Resins[MeSH Terms]) OR (Composite Resins)) OR (Composite)) OR (Dental Resins)) OR (Dental Resin)) OR (Dental)) OR (Dental)) OR (Resin composite))) AND (((((degree conversion) OR (conversion degree)) OR (degree cure)) OR (cure degree)) OR Polymerization[MeSH Terms]).	((TITLE-ABS-KEY (degree AND conversion)) OR (TITLE-ABS-KEY (conversion AND degree)) OR (TITLE-ABS-KEY (degree AND cure)) OR (TITLE-ABS-KEY (cure AND degree)) OR (TITLE-ABS-KEY (polymerization))) AND ((TITLE-ABS-KEY (composite AND resins)) OR (TITLE-ABS-KEY (composite AND resin)) OR (TITLE-ABS-KEY (dental AND resins)) OR (TITLE-ABS-KEY (dental AND resin)) OR (TITLE-ABS-KEY (resin AND composite))) AND ((TITLE-ABS-KEY (polywave AND led)) OR (TITLE-ABS-KEY (uv AND led)) OR (TITLE-ABS-KEY (broad AND spectrum AND led AND curing AND light)) OR (TITLE-ABS-KEY (dual-peak AND led)) OR (TITLE-ABS-KEY (polywave))) AND ((TITLE-ABS-KEY (second-generation AND lcu)) OR (TITLE-ABS-KEY (second-generation AND led AND curing AND light)) OR (TITLE-ABS-KEY (single-peak AND led y) OR (TITLE-ABS-KEY (monowave))) AND ((TITLE-ABS-KEY (led AND curing AND light)) OR (TITLE-ABS-KEY (led AND light-curing AND unit)) OR (TITLE-ABS-KEY (light AND curing)) OR (TITLE-ABS-KEY (light AND curing AND unit)) OR (TITLE-ABS-KEY (light-emitting AND diodes)) OR (TITLE-ABS-KEY (led AND dental AND curing AND lights)) OR (TITLE-ABS-KEY (dental AND curing AND light)) OR (TITLE-ABS-KEY (curing AND lights)) OR (TITLE-ABS-KEY (dental AND curing AND lights)))	1 (((((((ALL=(dental curing lights)) OR ALL=(dental curing light)) OR ALL=(LED dental curing lights)) OR ALL=(Light-emitting diodes)) OR ALL=(Light curing unit)) OR ALL=(Light curing)) OR ALL=(LED light-curing unit)) OR ALL=(LED curing light) 2: (((ALL=(second-generation LCU)) OR ALL=(Second-generation LED Curing Light)) OR ALL=(Single-peak LED)) OR ALL=(Monowave) 3: ((((ALL=(Polywave LED)) OR ALL=(UV LED)) OR ALL=(Broad spectrum LED curing light)) OR ALL=(Dual-peak LED)) OR ALL=(Polywave) 4:((((ALL=(composite resins)) OR ALL=(composite)) OR ALL=(resin)) OR ALL=(resin composite)) OR ALL=(dental resin) 5:((((ALL=(degree conversion)) OR ALL=(conversion degree)) OR ALL=(degree cure)) OR ALL=(cure degree)) OR ALL=(polymerization) 6: #5 AND #4 AND #3 AND #2 AND #1

Table 2: Descriptive data from included studies.

Author	Country	DC evaluation method	Monowave LED unit	Energy (J)	Polywave LED unit	Energy(J)	Resin-based material	Sp per group	Sp thickness (mm)	DC measurement
Ilie & Hickel, 2008	Germany	FTIR-ATR	BluePhase*	10s = 6,5 20s= 13	UltraLume LED 5[&] Prototype*	10s= 7,35 20s= 14,7 10s = 6,5 20s= 13	Heliobond* Excite*	6	2	Not informed
Brandt et al., 2011	Brazil	FTIR-ATR	UltraBlue IS[#]	35.8	UltraLume LED 5[&]	35.5	experimental composite resin	3	Not informed	Bottom
Santini el al., 2012	United Kingdom	micro-Raman spectroscopy	Bluephase*	35.38	Valo[&] Bluephase G2*	24.84 25.73	Tetric EvoCeram* Vit-l-escence[&] Herculite XRV Ultra[@]	5	2	Top and bottom

Santini et al., 2014	**United Kingdom**	**micro-Raman spectroscopy**	**Bluephase***	**23.4**	**Valo[&] Bluephase G2***	**24.8 25.7**	**Opal Bond[$] APC Plus[%] Light Bond[^]**	**3**	**2**	**Top and bottom**
Lucey et al., 2014	United Kingdom	micro-Raman spectroscopy	Bluephase*	32.2	Valo[&] Bluephase G2*	30 28.1	Vit-l-escence[&] Herculite XRV Ultra[@]	3	2	Top and bottom
Brandt et al., 2013	Brazil	mid-IR spectroscopy	UltraBlue IS[#]	35.8	UltraLume LED 5[&]	35.5	experimental composite resin	4	1	Not informed
Aguiar et al., 2011	Brazil	FTIR	Bluephase 16i**	22	UltraLume LED 5[&]	14	Z350[=]	12	1	Not informed
Brandt et al., 2010	Brazil	FTIR	UltraBlue IS[#]	35.8	UltraLume LED 5[&]	35.5	experimental composite resin	10	1	Not informed
Lee et al., 2012	Korea	FTIR	L.E. Demetron [@]	36	G-LIght***	36	Aelite LS Posterior Tetric EvoCeram Vit-l-escence Filtek Z350 Grandio	5	3	Top and bottom
Cardoso et al., 2017	Brazil	FTIR-ATR	Radii Plus"	18 36 56	Bluephase G2*	18 36 56	experimental composite resin	7	1 2	Bottom
Amato et al., 2016	Brazil	FTIR	Ortholux [%%]	17.2	Valo Cordless[&]	17.2	Transbond XT [%%] Opal Bond MV[&]	5	1	Not informed
Shimokawa et al., 2017	Canada	mid-IR FTIR-ATR	Custom designed	17.9 18.04	Custom designed	18.4 18.1	Filtek Supreme Ultra[=] Tetric EvoCeram* TPH Spectra High Viscosity [++]	5	2.5	Top and bottom
Lee et al., 2013	Korea	FTIR	L.E.Demetron 1[@]	36	G-light***	36	Grandio[?] Premise [@] Aelite LS[<] Estelite Sigma Quick[>] Filtek LS[=] Venus Diamond[{]	5	3	Top and bottom
Santos et al., 2018	Brazil	FTIR	Coltolux LED[!]	24	Bluephase G2*	24	IPS Empress Direct*	10	2	Top

Contreras et al., 2021	**Brazil**	**FTIR-ATR**	**MW LED curing unit==**	**23.48**	**Bluephase N***	**22.99**	**Tetric N-Ceram BulkFill* Admira fusion X-tra Bulk Fill? Tetric N-Ceram***	**5**	**2 4**	**Bottom**
Neto et al., 2022	Brazil	FTIR-ATR	DB685\\	10	Valo Cordless&	10	experimental adhesive	5	Not informed	Bottom
Al Nahedh et al., 2022	Saudi Arabia	FTIR	LED =		Bluephase G2*		Tetric N-Ceram Bulk Fill* Filtek Bulk Fill Posterior Restorative = Filtek Z350 XT =	10	4	Top, bottom and 2 mm
Oliveira et al., 2016	Brazil	FTIR-ATR	Radii “		Valo Cordless&		experimental composite resin	10	1	Not informed
Miletic, Santini, 2012	Serbia	micro-Raman spectroscopy	Bluephase*		Bluephase G2*		experimental composite resin	5	2	Top and bottom
Boeira et al., 2021	Brazil	FTIR-ATR	Radii-cal “ Emitter D ““	30.1 30.4	Valo Cordless& Bluephase N*	26,1 23,5	experimental adhesive	3	3 µL	Bottom
Siagian et al., 2020	Indonesia	FTIR	SmartLite Focus+++		Bluephase style*		Filtek Bulk Fill = Tetric N-Ceram Bulk Fill* SDR Flow ++++	5	4	Not informed

***Ivoclar Vivadent, Schaan, Lichtenstein**
****Vivadent, Bürs, Austria**
& Ultradent Products Inc., South Jordan, UT, USA
 # DMC Equip, São Carlos, SP, Brazil
@ Kerr Corporation,Orange, CA, USA
$ Opal Orthodontics, South Jordan, UT, USA
% 3M Orthodontic Products, 3M Center,St Paul, MN, USA
%% 3M Unitek, Monovia, CA, USA
^ Reliance Orthodontic Products, Inc., Itasca, IL, USA
+ Dentsply International, York, PA, USA
++ Dentsply, Milford, DE, USA
+++ Dentsply, Sirona
++ Dentsply, Milford, DE, USA
++++ Dentsply, Konstanz
= 3M ESPE Dental Products, St. Paul, MN, USA
= = 3M ESPE, Sumare, Brazil
“ SDI; Bayswater, Victoria, Australia
? VOCO, Cuxhaven, Germany
< Bisco, Inc., Schaumburg, IL, USA
> Tokuyama, Tokyo, Japan
{ Heraeus Kulzer GmbH, Hanau, Germany
! Coltène Whaledent, Altstätten, Switzerland
\\ Dabi Atlante, Ribeirão Preto, SP, Brazil
““ Schuster, Santa Maria, Brazil
*****GC Corp., Tokyo, Japan**

Table 3: Risk of bias assessment

Author	Random	Sample size	Same sp number	Single operator	manufacturer's instructions	Blinded Operator	Risk of bias
Ilie & Hickel (2008)	N	N	Y	N	Y	N	HIGH
Brandt et al., (2011)	N	N	Y	N	N	N	HIGH
Santini et al., (2012)	N	N	Y	N	Y	N	HIGH
Santini et al., (2014)	S	N	Y	N	N	N	HIGH
Lucey et al., (2014)	N	Y	Y	N	Y	N	MEDIUM
Brandt et al., (2013)	N	N	Y	N	N	N	HIGH
Aguiar et al., (2011)	Y	N	Y	N	Y	N	MEDIUM
Brandt et al., (2010)	N	N	Y	N	N	N	HIGH
Lee et al., (2012)	N	N	Y	N	Y	N	HIGH
Cardoso et al., (2017)	N	N	Y	N	N	N	HIGH
Amato et al., (2016)	N	N	Y	N	Y	N	HIGH
Shimokawa et al., (2017)	N	N	Y	N	N	N	HIGH
Lee et al., (2013)	N	N	Y	N	Y	N	HIGH
Santos et al., (2018)	N	N	Y	N	Y	N	HIGH
Contreras et al., (2021)	Y	N	Y	N	Y	N	MEDIUM
Neto et al., (2022)	N	N	Y	N	N	N	HIGH
Boeira et al., (2021)	N	N	Y	N	Y	N	HIGH
Al Nahedh et al., (2022)	N	N	Y	N	Y	N	HIGH
Oliveira et al., (2016)	N	N	Y	N	N	N	HIGH
Miletic & Santini, (2012)	N	N	Y	N	Y	N	HIGH
Siagian et al., (2020)	N	N	Y	N	N	N	HIGH

3. CONCLUSION

This dissertation analyzed the currently available literature, through systematic review and meta-analysis, regarding the effectiveness of polywave LEDs in the degree of conversion of resinous composites (composite resins and adhesive systems) compared to monowave devices.

Camphorquinone is the most used molecule to initiate the polymerization reaction, but due to its aesthetic disadvantage, alternative molecules have been developed to ensure better aesthetic results without compromising mechanical properties, which requires the light units to incorporate wavelengths below the blue, justifying the emergence of polywave LEDs.

The present study shows that polywave LED devices produce a higher degree of conversion in composite resins when compared to monowave LEDs.

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APPENDIX A- Risk of bias according to robdemat tool

	D1 Bias in planning and allocation			D2 Bias in sample/specimen preparation		**D3 Bias in the evaluation result**		D4 Bias in data processing and results reporting	
author	**presence of control group**	**randomization of samples**	**justified sample size**	**sample standardization**	**identical experimental conditions**	**appropriate and standardized tests to obtain results**	**operator blindness**	**statistical analysis**	**Reports study results**
ILIE & HICKEL (2008)	sufficiently reported	not reported	not reported	not reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
BRANDT et al (2011)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
SANTINI et al (2012)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
SANTINI et al (2014)	sufficiently reported	insufficient reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
LUCEY et al (2014)	sufficiently reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
BRANDT et al (2013)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
AGUIAR et al (2011)	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
BRANDT et al (2010)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
LEE et al (2012)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	insufficient reported
CARDOSO et al (2017)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
AMATO et al (2016)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
SHIMOKAWA et al (2017)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	insufficient reported
LEE et al (2013)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
SANTOS et al (2018)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
CONTRERAS et al (2021)	sufficiently reported	insufficient reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	insufficient reported
NETO et al (2022)	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
AL NAHEDH et al., 2022	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
OLIVEIRA et al., 2016	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
MILETIC, SANTINI, 2012	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	sufficiently reported	sufficiently reported
BOEIRA et al., 2021	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported
SIAGIAN et al., 2020	sufficiently reported	not reported	not reported	sufficiently reported	sufficiently reported	sufficiently reported	not reported	insufficient reported	sufficiently reported

APPENDIX B - GUIDELINES FOR PUBLICATION IN THE JOURNAL OF APPLIED ORAL SCIENCE

INSTRUCTIONS TO AUTHORS

Scope and policy

1 SCOPE

The Journal of Applied Oral Science (JAOS) it is committed to publishing the scientific and technological advances achieved by dental, and speech-language pathology and audiology communities, according to the quality indicators, with the objective of assuring its acceptability within its knowledge fields. The primary goal of JAOS is to publish the outcomes of original research/clinical investigations in the field of Oral Sciences, with emphasis in dentistry, speech-language pathology and audiology, and related areas.

Submissions of case reports (including case series and clinical protocols) and short communication are no longer accepted by JAOS, and review manuscripts (including systematic reviews) can only be submitted under the editor's invitation.

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1.1 Publication fee

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2 GENERAL GUIDELINES

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The papers sent for publication must be original and the simultaneous submission to another journal, either national or international, is not allowed. JAOS shall retain the copyright of all papers published, including translations; future reproduction as a transcription is allowed, provided the source is properly mentioned.

2.2 Acceptance of preprints

The JAOS is open for preprint submissions. A preprint is defined as a manuscript, ready for submission that is deposited on trusted preprint servers before or in parallel to the submission to a journal. Only submissions of papers previously deposited on these servers will be accepted, which will be duly evaluated for their recognition and quality by JAOS.

In case of acceptance and publication of the article in JAOS, the authors must update the registration status on the preprint server, informing the complete reference of the publication in the journal.

2.3 Research data and data repository

Research data corresponds to any information that has been observed, collected, generated, or created to validate original research findings. This includes raw data, processed data, audio, video, code, software, algorithms, protocols, and methods. While usually digital, research data also includes non-digital formats such as laboratory notebooks and diaries.

Authors must ensure that confidential data must not be shared to preserve the ethicality, legality, and privacy when appropriate, otherwise, consent to release data must be provided by the involved participants. Research data that are not required to verify the results reported in articles are not covered by this policy.

The preferred mechanism for sharing research data is via data repository, which consists in a relevant tool for the authors/contributors to archive and share organized original and processed research data with or without supplemental material. We encourage the use of good practice according to the Open Science to assure safety and transparency.

Among the JAOS recommended data repositories, the SciELO Data repository is included. It is a tax-free and open system, which enables the contributors to deposit research data in association to a specific manuscript. Using SciELO Data, authors should present the data ONLY after acceptance of the manuscript. JAOS follows a Research Data Policy Type 3 and adopts Level 1 Curation.

Data repositories to deposit your research data are available at https://repositoryfinder.datacite.org/. To ensure the quality and recognition of the data generated, JAOS recommends and follows the FAIR principles (Findable, Accessible, Interoperable, and Reusable).

To make these data available in accordance with SciELO's policies, authors must fill in the Open Science Compliance form.

Embargoes on data sharing are permitted. When publishing a dataset, the author may choose to defer the date at which the data becomes available. This means that the description and files of that dataset are not publicly available until the embargo date is reached. Meanwhile, other information about the dataset, such as the contributors, title, citation and associated articles, becomes available immediately prior to the embargo.

Sharing research data as supplementary information files is discouraged. For some types of data, research data sharing via Supplementary Materials is not allowed. Authors are encouraged to ensure that their datasets are either deposited in publicly available repositories presented in the main manuscript.

JAOS encourages authors to cite any publicly available research data in their reference list. References to datasets (data citations) must include a persistent identifier (such as a DOI). Citations of datasets, when they appear in the reference list, should include the minimum information recommended by DataCite and follow JAOS style.

Example:

Mahardawi B. The role of hemostatic agents following dental extractions: a systematic review and meta-analysis [dataset]. 2022 Mar 14 [cited 2022 Apr 22]. In: Dryad [Internet]. doi: 10.5061/dryad.59zw3r297. Available from: https://doi.org/10.5061/dryad.59zw3r297

JAOS encourages research data to be made available under open licenses that allow free reuse and recommends the adoption of the CC BY 4.0 License (Creative Commons Attribution 4.0 International) which authorizes the sharing, using, and adaptation of research data provided that credit to the authors is ensured, but the author can decide which Creative Commons License is best suited to the type of data deposited.

JAOS requires authors to include a Data Availability Statement to any article that report results derived from research data. The provision of a Data Availability Statement will be verified as a condition of publication and should present information on where the data supporting the results reported in the article can be found including, when applicable, hyperlinks to publicly archived datasets analyzed or generated during the study. When research data are not publicly available, this must be stated in the manuscript along with any conditions for accessing the data. Data Availability Statements commonly take one of the following forms:

- Data available in a publicly accessible repository

The datasets generated during and/or analyzed during the current study are available in the [NAME] repository, [DOI – PERSISTENT WEB LINK TO DATASETS].

- Data available on request due to restrictions, e.g., privacy or ethical

The datasets generated during and/or analyzed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

- Data sharing not applicable

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

- Data is contained within the article

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

- 3rd Party Data

The data that support the findings of this study are available from [third party name] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [third party name]

Questions about complying with this policy should be sent to jaos@usp.br.

2.4 JAOS will only accept submissions of manuscripts written in English. The English language should also be adopted in all documents during the procedures involving the articles. The content of the texts, quotations, and references of the papers submitted and published are of the sole responsibility of the authors, not necessarily reflecting the opinion of JAOS's Editor-in-Chief or Editorial Board.

2.5 JAOS has the right to submit all manuscripts to the Editorial Board, which is fully authorized to determine the appropriateness of their content to peer review (otherwise, manuscripts will receive an Immediate Rejection decision), and the subsequent decision regarding acceptance/rejection, or return them to the authors with suggestions and modifications to the text and/or for them to adapt it to the editorial standards of the journal. In this case, the manuscript will be reevaluated by the Editor-in-Chief and the Editorial Board.

2.6 The dates of receipt of the original article was received and accepted will appear when published in the JAOS.

2.7 JAOS is published exclusively in electronic format.

3 EVALUATION CRITERIA

3.1 Pre-evaluation: manuscripts will be appreciated by Editors-in-Chief and Associate Editors for their adequacy to the Journal's scope, priority and potential publication and citation impact, degree of novelty and methodology. Manuscripts that do not meet the set of these requirements at this step will be rejected and returned to authors, while the manuscripts considered adequate will follow the regular peer review process.

3.2 Technical review: manuscripts approved in the pre-evaluation stage will be then evaluated for their compliance to the publication norms and presence of mandatory documents required for submission to JAOS. Manuscripts not in accordance with instructions will be returned to authors for adjustments before being reviewed by Associate Editors and referees.

3.3 Merit and content evaluation: papers approved by Associate Editors will be evaluated in their scientific merit and methods by at least two ad hoc referees from different institutions of that of the authors, besides the Editor-in-Chief.

3.3.1 As part of the evaluation process, all manuscripts, in all rounds of the review, will be submitted to analysis by a plagiarism software.

3.3.2 The Editor-in-Chief will decide on manuscript acceptance. When revision of the original is required, the manuscript will be returned to the corresponding author for modification. A revised version with modifications will be re-submitted by the authors, and that will be re-evaluated by the Editor-in-Chief, Editorial Board, and ad hoc referees, if necessary.

3.4 After approval of the scientific merit, manuscripts will pass through a final review performed by a professional assigned by JAOS. If manuscripts are still considered inadequate, they will be returned to authors for revision.

3.5 Authors and referees will be kept anonymous during the review process.

4 GALLEY PROOFS

4.1 Galley proofs of each article will be sent to the corresponding author by electronic mail in PDF format for final approval.

4.2, If necessary, authors will have 48 hours to make corrections and return the revised article.

4.3 The only corrections accepted will be minor spelling corrections and the verification of figures. Major corrections will cause the manuscript to undergo a new revision by referees and delay its publication.

4.4 If the galley proof is not returned in 48 hours, the Editor-in-Chief will consider it the unchanged final version.

4.5 Inclusion of new authors is not allowed at this stage of the publication process.

4.6 It is the sole responsibility of the authors to verify the proper use of their citation names and affiliation in the manuscript.

Form and preparation of manuscripts

1 PRESENTATION OF THE MANUSCRIPT

1.1 Structure of the manuscript

1.1.1 Cover page must be submitted as a supplementary file and should contain only:

- Title of the manuscript in English.
- Names of the authors in direct order with their respective affiliations in English. Affiliations must be written in Portuguese for Brazilian authors, in Spanish for Latin-American authors, and in English for the other nationalities.
- Full address of the corresponding author, to whom all correspondence should be addressed, including phone number as well as e-mail address.
- Information about the deposit of the manuscript on a preprints server, when applicable, indicating the access address and DOI number, if required (attach the Open Science Compliance form). Citation and referencing of the research data specifying the repository and the DOI number (attach the Open Science Compliance form).
- Mandatory note stating whether the manuscript is derived from any dissertations or theses and their respective access address when available.

1.1.2 Text

- The paper must be previously translated into English language or proofread by a copyediting company or professional.

Authors with English as native language must submit as supplementary file a signed letter taking responsibility for the quality of the English language and editing of the text.

- Title of the manuscript in English.
- Abstract structured in a sole paragraph: should comprise at most 300 words, highlighting a little introduction, objective, methodology, results, and conclusions.

• Keywords: words or expressions that identify the contents of the manuscript. The authors must check both MeSH and DeCS. Authors must use periods to separate the keywords, which must have the first letter of the first word in capital letters. Ex: Dental implants. Fixed prosthesis. Photoelasticity. Passive fit.

• Graphical abstract: A graphical abstract is a visual format of the manuscript to summarize the essential findings of the study. It helps to promote easy and concise information that can be quickly embedded by the readers and helps to be shared, including in social medias. Therefore, JAOS encourages this submission. An original figure that states clearly the sequence described in the manuscript needs to be designed (JPEG, minimum of 300 dpi and 1328 x 531 pixels (w x h)) and submitted as a separate file as supplementary material.

Examples: https://www.instagram.com/p/CL44dlbF-wu/

https://www.instagram.com/p/CVh4M9aFsGw/

https://www.instagram.com/p/CHhyixyFkag/

• Introduction: summary of the rationale and proposal of the study including only relevant references. It should clearly state the hypothesis of the study.

• Methodology: the material and the methods are presented with enough detail to allow confirmation of the findings. Include the city, state, and country of all manufacturers right after the first appearance of the products, reagents or equipment etc. Published methods should be referred to and briefly discussed, except if modifications were made. Indicate the statistical methods employed, if applicable. Please refer to item 3 for ethical principals and registration of clinical trials.

• Results: must be presented in a logical sequence in the text, tables, and illustrations. Data contained in tables and illustrations should not be repeated in the text, and only important findings should be highlighted. Please, use the fewest number tables and figures as possible.

- Discussion: this section should emphasize the new and important aspects of the study, discussing them with prior investigations. Any data or information mentioned in the introduction or results should not be repeated.The authors should stress the implications of their findings, as well as their limitations.

- Conclusion(s): Provide short conclusions that can be taken from the research. Go further than reaffirming the results, establishing relevant conclusions to the objectives based on the data. In most cases, the conclusions are only true for the study population.

- Acknowledgments (when appropriate): Acknowledge those who have contributed (person, laboratory, section, etc.) to the work. Specify sponsors, grants, scholarships and fellowships with respective names and identification numbers.

- References (please refer to item 2.3)

2 TECHNICAL NORMALIZATIONS

The text body of the manuscript should be typed as follows: 1.5 spacing in 11 pt Arial font, with 3-cm margins at each side, on an A4 page, adding up, to at most, 15 pages, thus including figures, tables, figure caption, and references.

2.1 Illustrations and Tables

2.1.1 The illustrations (photographs, graphs, drawings, charts, etc.), regarded as figures, should be limited to the least amount possible and should be uploaded in separate files, consecutively numbered with Arabic numbers according to the order they appear in the text.

2.1.2 All illustrations must be uploaded separately as individual files during the submission of the article. Photographs should be uploaded in .jpg format with at least 300 dpi and 10 cm width.

2.1.3 The tables should be logically arranged, consecutively numbered with Arabic numbers and the captions shall be placed above the tables. Tables should be open in the right and left laterals, removing any internal horizontal or vertical lines, as well as any colors or shades. Tables must be uploaded in .xls format.

2.1.4 The corresponding figure and table captions should be clear, concise and typed at the end of the manuscript as a separate list preceded by the corresponding number.

2.1.5 Footnotes for illustrations and tables should be indicated by asterisks and restricted to the least amount possible.

2.2 Citation of the Authors

Citation of the authors in the text may be performed in two manners:

1) Just numeric: ...and interfere with the bacterial system and tissue system.3,4,7-10

References must be cited in a numeric ascending order within the paragraph.

2) or alphanumeric

- one author - Gatewood31 (2012)
- two authors - Cotti and Mercuro19 (2016)
- three authors - Azar, Safi, Nikaein27 (2012)
- more than three authors - Gealh, et al.28 (2014)

2.3 References

The references must follow the "Uniform requirements for manuscripts submitted to Biomedical Journals - Vancouver" available at: http://www.nlm.nih.gov/bsd/uniform_requirements.html.

2.3.1 All references must be cited in the text. They should be numbered consecutively in the order in which they are first mentioned in the text. Abbreviations of the titles of the journals cited should follow MEDLINE.

2.3.2 Personal communications and unpublished data with no publication date must not be included in the reference list.

2.3.3 Theses, dissertations, monographs, and abstracts will not be accepted as references.

2.3.4 Avoid referencing articles published in languages other than English (if included, limit them to a maximum of 3). The English translation of the title must appear between brackets with the original title at the end of the reference.

2.3.5 The names of all authors should be cited, if up to 6 authors; in case there are more authors, the 6 first authors should be cited, followed by the expression ", et al.", which must be followed by period and should not be written in italics. Ex: Cintra LT, Samuel RO, Azuma MM, Ribeiro CP, Narciso LG, Lima VM, et al.

2.3.6 At most 40 references may be cited.

Examples of references:

Book

Preedy VR, organizator. Fluorine: chemistry, analysis, function and effects. London: Royal Society of Chemistry; 2015.

Book chapter

Buzalaf CP, Leite AL, Buzalaf MA. Fluoride metabolism. In: Preedy VR, organizator. Fluorine: chemistry, analysis, function and effects. London: Royal Society of Chemistry; 2015. p. 54-72.

Papers published in journals.

Conti PC, Bonjardim LR, Stuginski-Barbosa J, Costa YM, Svensson P. Pain complications of oral implants: Is that an issue? J Oral Rehabil. 2021;48(2):195-206. doi: 10.1111/joor.13112.

Papers published in journals in languages other than English.

Schubert O, Le V, Probst F. Chancen und Risiken von Zahnimplantaten [Dental implants - opportunities and risks]. MMW Fortschr Med. 2022;164(9):50-2. German. doi: 10.1007/s15006-022-0970-4

Online-only journal article (with electronic identifier)

Peixoto KO, Resende CM, Almeida EO, Almeida-Leite CM, Conti PC, Barbosa GA, et al. Association of sleep quality and psychological aspects with reports of bruxism and

TMD in Brazilian dentists during the COVID-19 pandemic. J Appl Oral Sci [Internet]. 2021 [cited 2022 June 20];29: e20201089. Available from: http://dx.doi.org/10.1590/1678-7757-2020-108.

Journal article with DOI

Francese MM, Gonçalves IV, Vertuan M, Souza BM, Magalhães AC. The protective effect of the experimental TiF4 and chitosan toothpaste on erosive tooth wear in vitro. Sci Rep. 2022;12(1):7088. doi: 10.1038/s41598-022-11261-1

Journal article Epub ahead of print/In press/Forthcoming

Pucciarelli MG, Toyoshima GH, Oliveira TM, Neppelenbroek KH, Soares S. Quantifying the facial proportions in edentulous individuals before and after rehabilitation with complete dentures compared with dentate individuals: a 3D stereophotogrammetry study. J Prosthet Dent. Forthcoming 2022. doi: 10.1016/j.prosdent.2022.03.013

Preprint

Weissheimer T, Só MV, Alcalde MP, Cortez JB, Rosa RA, Vivan RR, et al. Evaluation of mechanical properties of coronal flaring nickel-titanium instruments. Research Square rs-49258/v1 [Preprint]. 2020 [cited 2020 Sept 2]. Available from: https://doi.org/10.21203/rs.3.rs-49258/v1

Research data

Mahardawi B. The role of hemostatic agents following dental extractions: a systematic review and meta-analysis [dataset]. 2022 Mar 14 [cited 2022 Apr 22]. In: Dryad [Internet]. doi: 10.5061/dryad.59zw3r297. Available from: https://doi.org/10.5061/dryad.59zw3r297

Papers with more than 6 authors

The first 6 authors are cited, followed by the expression ", et al."

Bergantin BT, Di Leone CC, Cruvinel T, Wang L, Buzalaf MA, Borges AB, et al. S-PRG-based composites erosive wear resistance and the effect on surrounding enamel. Sci Rep. 2022;12(1):833. doi: 10.1038/s41598-021-03745-3

Volume with supplement and/or Special Issue

Ricomini AP Filho, Chávez BA, Giacaman RA, Frazão P, Cury JA. Community interventions and strategies for caries control in Latin American and Caribbean countries. Braz Oral Res. 2021;35(suppl 1): e054. doi: 10.1590/1807-3107bor-2021.vol35.0054

The authors are fully responsible for the correctness of the references.

3 ETHICAL PRINCIPLES AND REGISTRATION OF CLINICAL TRIALS

3.1 Experimental procedures in humans and animals

JAOS reassures the principles incorporated in the Helsinky Declaration and insists that all research involving human beings, in the event of publication in this journal, be conducted in conformity with such principles and others specified in the respective ethics committees of the authors' institution. In the case of experiments with animals, the same ethical principles must also be followed. When surgical procedures in animals were used, the authors should present, in the Methodology section, evidence that the dose of a proper substance was adequate to produce anesthesia during the entire surgical procedure. All experiments conducted in human or animals must accompany a description, in the Methodology section, that the study was approved by the respective Ethics Committee of authors' affiliation and provide the number of the protocol approval.

3.1.1 Papers presenting experimental studies in human volunteers or in animals must contain the Ethical Committee approval of the reports as mandatory supplementary file.

3.1.2 Papers describing studies in animals must be submitted with the ARRIVE Checklist as mandatory supplementary file. The ARRIVE Checklist is available at https://mc04.manuscriptcentral.com/societyimages/jaos-scielo/ARRIVEChecklist.docx

3.1.3 Ethics Committee certificate written in different languages from English, Spanish, and Portuguese must be fully translated into English.

3.2 Clinical Trial Registration involving human subjects.

JAOS supports the policies of the World Health Organization (WHO) and the International Committee of Medical Journal Editors (ICMJE) for the registration of clinical trials. The journal recognizes the importance of such initiatives for the registration and international dissemination of clinical studies with an open access. Therefore, JAOS will publish only the clinical trials that have previously received an identification number validated by the criteria established by the WHO and ICMJE.

Clinical trials are referred as any research study that prospectively or retrospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate health effects and outcomess. Interventions include but are not restricted to drugs, cells and other biological products, surgical procedures, radiologic procedures, devices, behavioral treatments, process-of-care changes, preventive care, etc.

3.2.1 Manuscripts presenting interventional clinical trials in human volunteers must be submitted with the following mandatory supplementary files:

- CONSORT 2010 or SPIRIT checklist
- registration number of the research in a database that meets the requirements of the WHO and the ICMJE
- Suggestions: for Brazilian authors
- Suggestions for Brazilian and non-Brazilian authors/ (ISRCTN).

Submissions with a registration date after the date of submission of the article to JAOS will not be accepted.

3.2.2 Manuscripts that involve observational clinical trials in human volunteers must be submitted with two mandatory supplemental files:

- STROBE checklist.
- registration confirmation number of the research in a database that meets the requirements of the WHO and the ICMJE

Submissions with a registration date after the date of submission of the article to JAOS will not be accepted.

3.2.3 Manuscripts that involve surveys with human volunteers must be submitted with two mandatory supplemental files:

- CHERRIES checklist.
- registration confirmation number of the research in a database that meets the requirements of the WHO and the ICMJE.

Submissions with a registration date after the date of submission of the article to JAOS will not be accepted.

3.3 Systematic Reviews

Systematic Reviews SHOULD ONLY BE SUBMITTED AT THE INVITATION OF JAOS. And even in these cases, JAOS will only receive Systematic Reviews of any kind (Traditional, Overviews, Umbrella Reviews, and Scoping Reviews) if they meet the following mandatory requirements:

- PRISMA 2020 checklist statement duly filled, including all applicable extensions for particular cases.
- PROSPERO International Prospective Register of Systematic Reviews or Open Science Framework

Submissions with a registration date after the date of submission of the article to JAOS will not be accepted.

3.4 The Editor-in-Chief and the Editorial Board reserve the right to refuse manuscripts that show no clear evidence that these principals were followed or in which the methods used were considered inappropriate for experiments in humans or animals.

4 ANY FURTHER QUERIES SHALL BE SOLVED BY THE EDITOR-IN-CHIEF AND EDITORIAL BOARD