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Effect of curcumin-mediated photodynamic therapy on *Streptococcus mutans* and *Candida albicans*: A systematic review of in vitro studies

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ABSTRACT

Background: There is still no systematized evidence in the literature regarding the combination of curcumin to improve the effects of antimicrobial photodynamic therapy (aPDT) on complex oral biofilms. Therefore, the objective of this review was to systematically assess the antimicrobial effect of curcumin-mediated aPDT on the vitality of biofilms of microorganisms *Streptococcus mutans* and *Candida albicans*.

Methods: The addressed focused question was: "What are the effects of curcumin-mediated antimicrobial therapy on the biofilm viability of *Streptococcus mutans* and *Candida albicans* in vitro models?" A literature search was conducted in the electronic databases Pubmed, Web of Science, Scopus, Cochrane Library and Bireme up to April 2019. In vitro studies evaluating the effect of curcumin-mediated antimicrobial photodynamic therapy on S. mutans and C. albicans biofilms were included.

Results: From 95 citations, 11 full-text articles were screened and 6 studies were included in this review. Because of the heterogeneity observed in the studies selected, meta-analysis was not possible.

Conclusions: The in vitro studies indicate the potential use of curcumin-mediated aPDT to inactivate microorganisms; *Streptococcus mutans* and *Candida albicans*. This survey should be viewed as a starting point for further examinations using standardized parameters to enhance outcomes.

1. Introduction

The oral cavity contains a heterogeneous, copious and complex arrangement of various microbial biological systems that communicate with the host under physiological or pathological conditions [1,2]. Numerous microbial species are sorted out in biofilm structure, which is made for microorganisms by a firmly followed polymer network in dental surface [3]. These structures have specific favorable circumstances that shield them from host protections and treatment [1,4].

The disharmonic connection between oral microbiota parts may prompt the infection process [1]. One of the primary illnesses found in the oral cavity is dental caries [5]. Dental caries often result from a change in metabolic movement brought about by change in biofilm environment, which causes a disruption between dental minerals and biofilm liquids [3].

Streptococcus mutans are the most generally discovered microbes in biofilms that injure dental veneer, being viewed as a primary pathogen [2].So is *Candida albicans*. These organisms pathogenicity is also affected by host conditions [6] and is enhanced by biofilm formation [7].

Photodynamic treatment (PDT) is a treatment methodology that connects a light source with a photosensitizing operator. Appropriate illumination results in generation of reactive oxygen specimens able to oxidize natural atoms [8]. It's an elective treatment that can be connected for various purposes, for example, malignant growth treatment and dermatological conditions [9]. In the oral cavity, PDT is utilized for oral injuries treatment, for example, mucositis and herpes [10,11], and for antimicrobial way to deal with diminish followed biofilms (framed for microbes, organisms, infections and yeasts) in teeth and delicate tissue [12]. Along these lines, PDT rose as an option for treatment of biofilms ailments, for example, dental caries, oral candidiasis, peri-implantitis, and periodontal illness, and it is known as antimicrobial photodynamic treatment (aPDT) [13,14]. The utilization of a light hotspot for aPDT is alluring, since blue LED (light emitting diode) is regularly utilized as a dental relieving gadget for polymerization of

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composite sap filling material in dental caries treatment. What's more, numerous investigations have so far been accounted for a bactericidal impact of blue LED [15–18].

Photosensitizers (PS) are fundamental non-harmful photosensitive mixes in aPDT [9]. It exhibits the specifically capacity to fuse into target cells and, when initiated by a light source with sufficient wavelength, it changes their ground state to the energized state [8]. The actuated state can happen through two photochemical components known as sort I and type II responses. In sort I response, the PS communicates with oxygen, exchanging electrons which lead to the creation of free radicals [19]. In sort II response, the exceedingly receptive singlet oxygen is produced because of vitality exchange to the triplet condition of subatomic oxygen [12]. The two systems may actuate apoptosis or putrefaction by cell parts oxidation, for example, proteins, nucleic acids, films and, thus, devastating target cells [20].

A few kinds of medications have been created to get perfect photosensitizers qualities [21]. In this sense, with developing enthusiasm for the utilization of characteristic mixes, curcumin shows up. It is a phenolic compound, extricated from roots and rhizomes of a herbaceous plant called *Curcuma longa*, known for helpful wellbeing impacts because of cancer prevention agent, calming, antimicrobial and anticancer properties [22–24]. At present numerous examinations are coordinated to curcumin use as PS in aPDT, despite the fact that the activity instrument isn't completely comprehended, curcumin shows high phototoxic movement in micromolar sums when illuminated in 300–500 nm wavelength run [25].

The antimicrobial impact against microorganisms present in oral cavity, including cariogenic microscopic organisms has just been exhibited in a few examinations with aPDT [4,26,27]. Due to the difficulty in standardization of the therapeutic concentration, formulation and parameters of the light source and its use, the objective of this work was to carry out a systematic review about the criteria for use of curcumin as PS in the reduction of two important pathogenic oral microorganisms: *Streptococcus mutans* and *Candida albicans*.

2. Materials and methods

2.1. Focused question

We focused our review question to address: “What are the effects of curcumin-mediated antimicrobial therapy on the biofilm viability of *Streptococcus mutans* and *Candida albicans* in vitro models?”

2.2. Selection criteria

This systematic review was conducted based on the guidelines of the Prisma Statement (www.prismastatement.org) [28] and on the PICOS model [29] for the definition of the inclusion criteria as follows: P (Population): “study sample consisting of biofilm cultures”, I (Intervention): “photodynamic therapy using LED with curcumine as PS”, C (Comparisons): “studies that have used other photosensitizers than curcumin” O (Outcomes): “cytotoxicity and photoinactivation of *S. mutans* and/or *C. albicans*”; and S (Study design): “in vitro studies”.

2.3. Search strategy

The electronic databases Pubmed, Web of Science, Scopus, Cochrane Library and Bireme were systematically searched using the combinations of the following Medical Subject Heading (MeSH) and text words: (“photochemotherapy”) OR (“photodynamic” AND “therapy”) OR (“photodynamic therapy”) AND (“curcumin”) AND (“streptococcus mutans”) OR (“streptococcus” AND “mutans”) AND (“candida albicans”) OR (“candida” AND “albicans”). Additionally, reference lists from retrieved publications were hand-searched. Language was restricted to English. All in vitro studies, except systematic reviews, were included. The literature search was concluded on April 15, 2019.

2.4. Screening methods and data extraction

Two examiners experienced in flag investigation played out the entire information extraction process freely. Talk occurred after each satisfied piece of the convention until accord was accomplished. The specialists autonomously screened all titles for qualification, in view of the from the earlier characterized PICOS consideration criteria. If there should arise an occurrence of difference, accord was accomplished through exchange. If there should be an occurrence of vulnerability, the investigation was made to the following stride. A while later, a similar procedure was performed to screen the edited compositions lastly to screen the full texts for qualification. In the event that no agreement was found after the exchange, a third examiner chose whether the investigation ought to be incorporated or prohibited. In the resulting procedure, the nature of the included investigations and the methodological attributes (consider quality/chance predisposition evaluation) were broke down for the chose examinations.

2.5. Data synthesis

Because of heterogeneity of sources of real intensity, wavelength, average fluency, power density of the incident radiation and photodynamic treatment among our selected 6 articles, a (statistical) meta-analysis for quantitative review was not possible. We were able to perform a qualitative systematic review. Next, the accompanying information were freely removed and examined by two specialists utilizing an institutionalized extraction structure: author/country, groups, types of bacterial species assessed, laboratory analysis, and main study outcomes.

3. Results

3.1. Study selection

Fig. 1 presents the flow chart of the selected studies. The literature search revealed a total of 95 records. After removal of duplicates, 45 papers remained to be screened on titles and abstracts. A number of papers (n = 34) did not meet the inclusion criteria by the abstract. Therefore, 11 full-text articles remained to be assessed for eligibility. After reading the full text, another 5 studies had to be excluded because it did not fulfill the inclusion criteria, which could not be perceived after reading the abstract, only after reading the full text. Finally, 6 studies were included in this review.

3.2. General characteristics of the selected studies

All studies selected for this review were published between 2011 and 2018. All included in-vitro studies originated from Brazil [25,30–33] and Taiwan [34]. A variety of bacterial species were assessed that includes *Streptococcus mutans, Candida albicans, Methicillin-Resistant Staphylococcus aureus (MRSA), Candida glabrata, Lactobacillus acidophilus,* and *Candida tropicalis.* All studies used the quantification of colonies as the primary laboratory method for analysis of cell viability after aPDT. The summary of effect of curcumin-mediated photodynamic therapy on *S. mutans* and *C. albicans* in biofilms is presented in Table 1 under the different conditions analyzed. In the included studies, three main topics were discussed: cell viability in the biofilm phase after photosensitization with all concentrations of curcumin tested; exposure to LED in different fluences; and the efficacy of light activated curcumin against biofilms of *S. mutans* and *C. albicans*. Data were extracted from the included studies as per following parameters: author/country, groups, types of bacterial species assessed, laboratory analysis, and main study outcome.

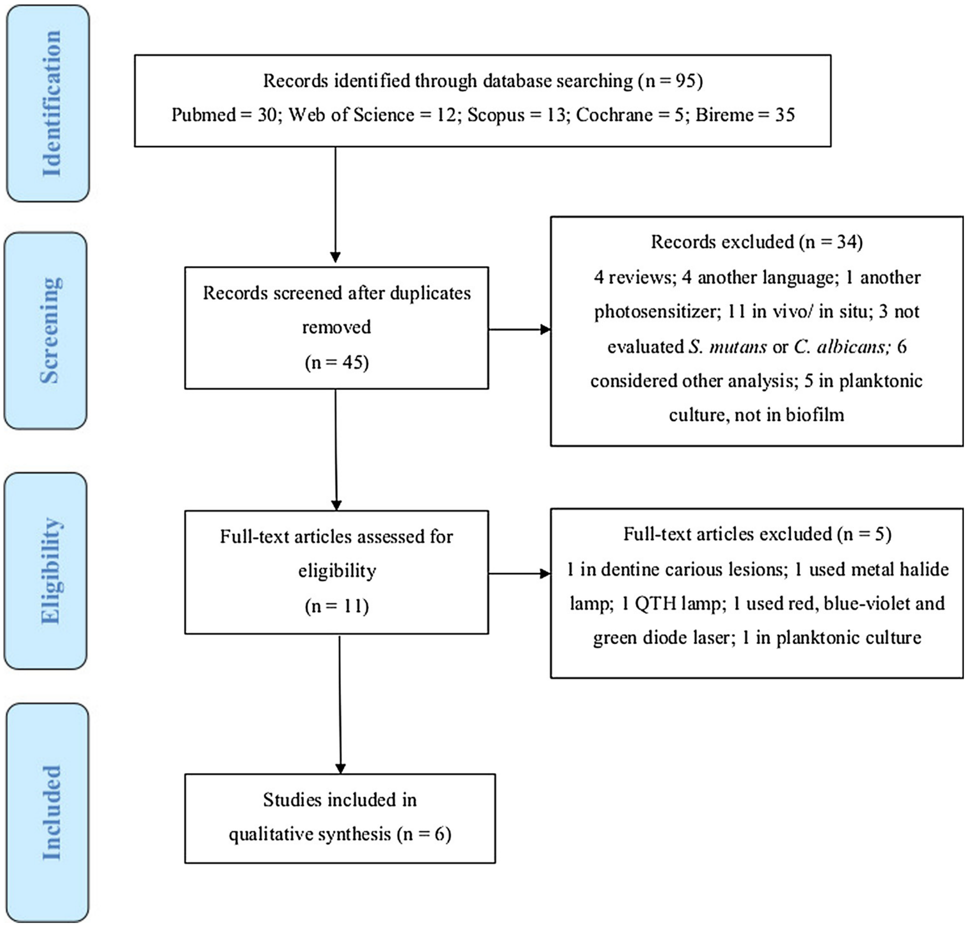

Fig. 1. Flow chart demonstrating the strategy used to identify in vitro studies for this systematic review (PRISMA guidelines is used to design this search strategy).

3.3. Photochemotherapy related parameters

All in-vitro studies included used light emitting diode (LED). The wavelengths of diode lasers used in the included PDT studies ranged from 403 nm to 460 nm. Energy fluence was reported in all the studies, except one [33]. Power output, Optic fibre diameter and Number of laser sessions were not reported in any study, assuming in the latter that only one session was performed in each experiment. The duration of irradiation was reported in all studies ranging from 5 to 30 min, except one who did not report this information [33]. All studies used curcumin as a photosensitizer, with its concentration varying from 1 to 1200 μM, with one study working with its anionic and cationic form [33]. All these data are detailed in Table 2.

3.4. Main outcomes of the studies

All in vitro studies reported a significant reduction in cell viability of *S. mutans* and *C. albicans* in the biofilm phase in aPDT after photosensitization with all concentrations of curcumin tested (Table 1). In general, most studies presented well-structured titles and summaries and contained a clear introduction with an experimental approach and rational explanation of the study objectives. Only one clearly pointed the scientific and statistical hypotheses of the study [33]. All studies provided the study design with sufficient detail for replication; gave fairly details of the statistical methods used to compare groups; showed a very rich scientific discussion, with implications and limitations of the study; and gave information that they repeated their experiments or measurement more than once.

4. Discussion

When we studied curcumin-mediated antimicrobial therapy, we came across contradictory results. A coherent path for trying to clarify these controversies was to rely only on the best quality studies on this subject. Based on this principle, we elaborated this systematic review of the literature. This research focused on this well-defined issue, which aimed to identify, select, evaluate and synthesize relevant available evidence. As the study of curcumin (CUR) in aPDT is a recent science, the older study that met the criteria for inclusion in this systematic review is from 2011.

PDT was evaluated since 1985 but the lack of specificity of PSs limited the extension of this therapy. Different PSs exist and have different indications on photodynamic therapy. This is the first systematic review that investigated the effects of curcumin-mediated antimicrobial therapy on the biofilm viability of *Streptococcus mutans* and *Candida albicans* in vitro models. Overall, all studies showed a significant reduction in the bacterial load.

However, there was a critical methodological heterogeneity and deficient data about laser and photosensitizer parameters in the included examinations. In the present survey, none of the examinations depicted the quantity of laser applications. It may be estimated that a solitary use of laser in PDT alone may be hard to keep up against bacterial impact for short follow-up period. Different elements, for instance, fiber distance across could impact control thickness and power yield in the utilization of laser amid PDT and could adjust the specific measure of vitality discharged amid the procedure, likely influencing the counter bacterial and subsequently mitigating impact of photodynamic treatment. In this survey, every single included examination for PDT demonstrated a critical decrease in the quantity of

Table 1
General description of included studies.

Author/Country	Groups	Bacterial species	Laboratory analysis	Main outcomes
Hsieh et al., 2018 [34]/*Taiwan*	Fluconazole + Photosensitizier + Light ● F-P-L- ● F + P + L- ● +P-L+ F + PDT Curcumin (μM) ● 1 ● 5 ● 10 ● 20 ● 40 ● 80	*C. albicans*	Quantification of colonies (CFU/mL) Cellular Morphology by SEM PDT-Induced Peroxidation of Membranes by FT-IR Microspectroscopy	Combination of fluconazole + PDT can inhibit C. albicans replication and eradicate biofilms completely.
Trigo Gutierrez et al., 2017 [33]/*Brazil*	Curcumin + Light ● C + L+ ● C + L- ● N ● C-L+ ● C-L-	*S. mutans; C. albians;* and *MRSA*	Confocal Scanning Laser Microscopy Quantification of colonies (CFU/mL)	Significant reduction of *C. albicans* and *S. mutans* after aPDT.
Quishida et al., 2016 [32]/*Brazil*	Photosensitizier + Light ● P + L+24 h ● P + L- 24 h ● P + L+48 h ● P + L- 48 h ● P-L+24 h ● P-L+48 h ● P-L- 24 H ● P-L- 48 H	*C. albicans; C. glabrata;* and *S. mutans*	Quantification of colonies (CFU/mL) Metabolic activity (XTT assay) Total biomass quantification Confocal laser scanning microscopy	Biofilms were susceptible to aPDT mediated by curcumin.
Araújo et al., 2014 [25]/*Brazil*	Light + Droug ● L-D- ● (control group) ● L-D+ ● L + D- ● L + D+	*S. mutans* and *L. acidophilus*	Survival fractions were calculated by counting the colonies	Significant reduction in cell viability in the biofilm phase following photosensitization with all curcumin concentrations tested.
Dovigo et al., 2011 [31]/*Brazil*	Photosensitizier + Light ● P-L- ● P-L+ 37,5 J/cm^2 ● P + L- ● PDT (J/cm^2) ● 5,28 ● 18 ● 25,5 ● 37,5	*C. albicans; C. tropicalis;* and *C. glabrata*	Metabolic activity (XTT assay) Quantification of the cells by CV assay	Significant reduction in *C. albicans* viability observed after PDT.
Dovigo et al., 2011 [30]/*Brazil*	PDT + Light ● P-L- PDT Curcumin (μM) ● 5 ● 10 ● 20 ● 30 ● 40	*C. albicans*	Metabolic activity (XTT assay) Quantification of colonies (CFU/mL)	Curcumin-mediated PDT decreased the biofilm biomass of the evaluated specie.

PDT = Photodynamic therapy; P = Photosensitizier; L = Light; SEM = Scanning Electron Microscopy; FT-IR = Fourier transform infrared; C = Curcumin; CUR-NP = Curcumin polymeric nanoparticle; CFU/mL = colony-forming units per milliliter; XTT assay = is a colorimetric assay that detects the cell viability; CV = Crystal violet.

microorganisms. In this way, it creates the impression that PDT could assume a crucial job in lessening bacterial burden in biofilms.

Both studies by Dovigo et al. [30,31] have evaluated the photodynamic effects of curcumin against *Candida albicans*. Both used the same light source with the same mean irradiance (LED device provided a uniform emission from 440 to 460 nm, with mean irradiance delivered of 22 mW/cm^2) but with different curcumin concentrations.

Dovigo et al. [30], demonstrated the helplessness of *C. albicans* biofilms to deadly photosensitization. The curcumin concentrations tested were 5, 10, 20, 30 and 40 μM, followed by illumination of 5.28 J/cm^2. In examination with the control gathering, a measurably critical decline in metabolic action was watched for all curcumin focuses tried. An immediate connection between curcumin focus and biofilm practicality was likewise watched. It has been that as the focus expanded the metabolism / viability diminished.

Dovigo et al. [31] shows the effect of PDT mediated by different concentrations of curcumin on the metabolic activity of *C. albicans, C. tropicalis* and *C. glabrata biofilms*. They noted that the lowest values of metabolic activity of *C. albicans* biofilms were observed with the use of 40 mM of curcumin, associated with both 5.28 and 18 J/cm2 of absorbance values. This study also evaluated the quantification of biofilm biomass using Crystal Violet (CV) assay and it was noticed that biofilm biomass was altogether lower in the PDT tests ($P < 0.05$). The study by Araújo et al. [25] evaluated the susceptibility of *Streptococcus mutans* to the effects of curcumin-mediated photodynamic antimicrobial therapy on biofilms compared with carious dentin. They used a blue LED with a real intensity of 19 mW/cm^2 in the solution for each well and central wavelength of 450 nm. This was one of the articles that least detailed statistical methods and analyzes used. Their aftereffects of least huge contrast tests demonstrated that the examples treated with curcumin

Table 2
Laser parameters of included studies.

Authors	Type of laser	Wavelength (nm)	Energy fluence (J/cm^{-2})	Power output (mW)	Power density ($mW\ cm^{-2}$)	Duration of irradiation (minutes)	Optic fibre diameter (mm)	Types of PS	Pre-irradiation time (minutes)	Concentration of PS (µM or g/L)
Hsieh et al., 2018 [34]	LED	403 450	9	NA	NA	30	NA	• Curcumin • Ascorbic acid	NA	• 1 µM • 5 • 10 • 20 • 40 • 80
Trigo Gutierrez et al., 2017 [33]	LED	440 - 460	NA	NA	33,58	NA	NA	• Free CUR • A-CUR-NP • C-CUR-NP	40	• 1200 µM • 260 • 260
Quishida et al., 2016 [32]	LED	440 - 460	37,5	NA	22	29	NA	• Curcumin	20	• 80 µM • 100 • 120
Araújo et al., 2014 [25]	LED	450	5,7	NA	19	5	NA	• Curcumin and curcuminoids	NA	• 0,75 g/L • 1,5 • 3 • 4 • 5
Dovigo et al., 2011 [31]	LED	440 - 460	5,28 18	NA	22	NA	NA	• Curcumin	NA	• 20 µM • 30 • 40
Dovigo et al., 2011 [30]	LED	440 - 460	5,28	NA	22	29	NA	• Curcumin	20	• 5 µM • 10 • 20 • 30 • 40

LED = light emitting diode; PS = photosensitizer; CUR = Curcumin; A = anionic; C = cationic; NP = nanoparticles; NA = not available.

pursued by blue light, showed an altogether more noteworthy decrease in the quantity of microscopic organisms than any other gathering whatsoever curcumin focuses utilized. The introduction of the biofilm to 0.75, 1.5, and 3.0 g/L curcumin and ensuing enlightenment with light brought about 97.5, 95, and 99.9% decreases in feasible cells, individually. At the point when the curcumin focus was 4.0 and 5.0 g/L, a lessening of 100% was gotten.

These outcomes appear differently in relation to the announcement by Dovigo et al. [31], which expresses that when microorganisms are sorted out in biofilm just a decrease in the quantity of microorganisms can be watched and the total disposal isn't accomplished. As indicated by Ramage et al. [35], there is a direct connection between the expansion in cell thickness, coming about because of the ideal opportunity for the advancement of the biofilm, and the expansion in its metabolic action. Be that as it may, because of light entrance and medication dissemination troubles, these microorganisms inside dentine carious injuries were less influenced than in the biofilm stage. Quishida et al. [32] evaluated the photodynamic inactivation of a multispecies biofilm using curcumin and LED light, including *C. albicans* and *S. mutans*. The final concentrations of 80, 100, and 120 µM were used and exposed to LED in the blue region, with emission from 440 to 460 nm, intensity of light emitted of 22 mW/cm^2 and fluence of 37.5 J/cm^2. The authors demonstrated that when biofilms were developed for 24-h, API (antimicrobial photodynamic inactivation) with curcumin + LED brought about noteworthy distinction contrasted with control for all curcumin fixations. The use of light did not influence the reasonability of *C. albicans*, however treatment with curcumin alone at 100 and 120 µM exhibited noteworthy distinction contrasted with control. As indicated by Dovigo et al., [30] the relationship of curcumin with light has been proposed to potentiate its antifungal activity. In the 48-h biofilm, the microorganisms *S. mutans* introduced a decrease in cell practicality for the three groupings of CUR when related with LED light, though for *C. albicans*, the decrease in $\log_{10}$ (CFU/mL) values was gotten just for the most elevated focus utilized. In this manner, the more powerful engineering of the biofilm shaped by *C. albicans* may have been an applicable factor that made it hard for the PS curcumin to follow up on the biofilm. Likewise, for the 48-h biofilm, varying from the 24-h biofilm, none of the convergences of curcumin without light was prepared to do diminishing the cell feasibility of the microorganisms assessed. In this way, it might be proposed that the higher opposition of the 48-h biofilm made it hard for API to act on the microorganisms.

Trigo Gutierrez et al. [33] used curcumin free and positively/negatively charged, encapsulated in nanoparticles for photodynamic therapy. A LED device having a wavelength from 440 nm to 460 nm and a light intensity of 33.58 mW/cm^2 was designed as a light source for photodegradation and aPDT experiments against mono-, dual- and triple-species biofilms of *C. albicans, S. mutans,* and *MRSA (Methicillin-Resistant Staphylococcus aureus)*.

In the mono-species biofilms, when the free curcumin was assessed, a noteworthy decrease of $\log_{10}$ (CFU/mL) of biofilms of *C. albicans* and *S. mutans* was seen after the aPDT contrasted with the control. For *S. mutans*, the aPDT intervened by the anionic CUR-NPs (curcumin in polymeric nanoparticles) advanced a noteworthy decrease in its practicality contrasted with different gatherings. The assessment of the cationic CUR-NPs against *C. albicans* showed that the estimations of every single test bunch were altogether lower than the control gathering. The contagious monospecies biofilm submitted to light just indicated $\log_{10}$ (CFU/mL) values essentially lower than the control and higher than different gatherings. Whenever *S. mutans* was assessed, they exhibited that biofilm treated with cationic NPs were essentially lower than the control and light-just gatherings.

In the aPDT against double-species biofilm, for the free CUR, the biofilm of *S. mutans* and *C. albicans* demonstrated a noteworthy decrease after the aPDT just for *C. albicans* contrasted with the control. For the biofilms of *S. mutans* and *MRSA*, they showed a noteworthy impact in the feasibility of *S. mutans*. Results got in this examination utilizing free CUR concur with past investigations which indicated restraint of double species biofilm made out of *S. mutans* and *L. acidophilus* by aPDT interceded by CUR [36]. The assessment of the anionic CUR-NPs against the biofilm of *S. mutans and C. albicans* exhibited for both, a noteworthy distinction ($p = 0.010$) between the aPDT gathering and the control gatherings. In the biofilm of *MRSA* and *C. albicans*, the aPDT interceded by the anionic CUR-NP brought about a critical contrast in the contagious reasonability contrasted with different gatherings. Contrasted with the control gathering, the aPDT decreased the suitability of *C. albicans* by 1.37 $\log_{10}$. At the point when the cationic CUR-NPs were assessed against the biofilm of *S. mutans* and *C. albicans*, the creators showed a critical contrast in the reasonability of the two species. At long last, in the biofilm of *S. mutans* and *MRSA*, the aPDT utilizing the cationic CUR-NPs advanced a noteworthy decrease in the suitability of S. mutans, with a decrease of 4.11 $\log_{10}$ contrasted with the control.

In the aPDT against triple-species biofilms, the outcomes acquired with the expectation of complimentary CUR indicated noteworthy contrasts among the treatment bunches for all microorganisms ($p < 0.001$). The assessment of the triple-species biofilm after medications with the anionic plans showed a huge contrast just for *C. albicans*. At the point when cationic definitions were thought about, critical contrasts were watched for the three microorganisms, which demonstrated comparable development conduct after the medications.

The most recent study of this systematic review, Hsieh et al. [34], evaluated the viability of *C. albicans* after treatment with antifungal agent and the effects of combined treatment with photodynamic and chemical therapies on *Candida albicans*. The excitation and monitored emission wavelengths were 403 nm and 450 nm, respectively. However, this is the only article that does not give us the specific model and brand of LED laser used. The accumulated photoenergy after 30 min of illumination was 9 J/cm2. Curcumin solutions used to *C. albicans* suspensions of 1, 5, 10, 20, 40, and 80 μM concentrations. At curcumin centralizations of 5 μM or higher, PDT dispensed with all *C. albicans* settlements. In this way, joining fluconazole with PDT can both restrain *C. albicans* replication and destroy biofilms totally. Eminently, the destruction of biofilms is to totally repress the harmfulness of the parasitic pathogens and to anticipate sedate obstruction in the synthetic treatment.

C. albicans in biofilms are more medication safe and destructive. The scattering is a significant advance in the improvement of *C. albicans* biofilms, and biofilm development can significantly decrease the adequacy of antifungal specialists [37]. In any case, the outcomes demonstrated that discontinuous PDT light enormously upgraded the impact, and fundamentally diminished cell reasonability. This improvement ought to be attributed to the fast photobleaching of curcumin [30]. Anyway, great antifungal treatment requires the advancement of an increasingly productive treatment that completely avoids replication.

In any case, in view of the aftereffects of included examinations, it is proposed that the job of PDT in diminishing bacterial burden in oral biofilms is gainful. Moreover, further in-vitro investigations ought to be attempted so as to welcome the treatment result. Hence, considers with institutionalized control and test bunches are proposed to approve the definitive impact of PDT in the decrease of bacterial burden. Finally, the results of the current deliberate survey that contains just in vitro investigations clearly may not be summed up to in vivo conditions. The unmistakable ecological elements, for example, flexible plaque development and gathering, variable salivation, have resistant framework, and restricted availability can't be built up in vitro investigations.

In conclusion, this systematic review showed decrease in the bacterial burden with the use of PDT.

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Declaration of Competing Interest

The authors have nothing to disclose and have no conflict of interest to declare.

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