العـــدد 17S حزيران 2025
No.17S JUNE 2025
المجلة العراقية للبحوث الإنسانية والإجتماعية والعلمية
Iraqi Journal of Humanitarian, Social and Scientific Research
Print ISSN 2710-0952 Electronic ISSN 2790-1254

دراسة الاختلافات بين ليزر أشباه الموصلات وليزر الحالة الصلبة: تطبيقات في طب الأسنان واصلاح الأنسجة

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الملخص

الهدف: كان الهدف من المراجعة المنهجية والتحليل البعدي Meta-Analysis and Systematic Review الحاليين هو مقارنة فعالية وتطبيقات ليزر أشباه الموصلات وليزر الحالة الصلبة في مجال الفيزياء التطبيقية، وخاصةً في سياق التطبيقات الطبية مثل التئام الجروح واصلاح/علاج الأنسجة وعلاجات الأسنان .المنهجية: أُجري بحث شامل في قواعد البيانات العلمية مثل PubMed و IEEE Xplore وScienceDirect وGoogle Scholar. بحثنا في المقالات، وضمّنّا المقالات المكتوبة باللغة الإنجليزية فقط بين عامي 2010 و2023. وشملت الكلمات المفتاحية المستخدمة في البحث "الليزر أشباه الموصلات أو ليزر الحالة الصلبة" و"التطبيقات أو الفعالية" و"طب الأسنان أو إصلاح الأنسجة أو الالتهاب أو القرحة". تم تحديد 197 مقالة مبدئيًا، وبناءً على معايير الإدراج والاستبعاد، تم تضمين 14 مقالة في هذه المراجعة. النتائج: شملت الدراسة 14 مقالاً من عام 2008 إلى عام 2021، مع التركيز على التجارب المُحكمة، وتقارير الحالات، والدراسات السريرية، والدراسات المقارنة، والدراسات المُقارنة في المختبر. أُجري تحليل تلوي لتحليل البيانات. تشير نتائج المراجعة إلى أن كلاً من ليزر أشباه الموصلات وليزر الحالة الصلبة قد أظهر فعالية في تطبيقات طبية مُختلفة. تراوحت جودة الدراسات المُشمولة بين المُتوسطة والمُرتفعة. أظهر كلٌ من ليزر أشباه الموصلات وليزر الحالة الصلبة تأثيرًا كبيرًا في الطب السريري. ومع ذلك، في حالة التئام الجروح، أظهر ليزر الحالة الصلبة تفوقًا . الاستنتاجات: ثبتت فعالية استخدام كلٍ من ليزر أشباه الموصلات وليزر الحالة الصلبة في التطبيقات الطبية، وخاصةً في طب الأسنان وإصلاح الأنسجة، ولكن هناك حاجة إلى دراسات إضافية لتحديد نوع الليزر الأمثل لتطبيقات مُحددة. بالإضافة إلى ذلك، يُعد توحيد تصميم الدراسة وتقارير النتائج أمرًا ضروريًا لتحسين جودة الأدلة في هذا المجال.

الكلمات المفتاحية: العلاج بالليزر؛ ليزر أشباه الموصلات؛ ليزر الحالة الصلبة؛ التطبيق؛ طب الأسنان؛ إصلاح الأنسجة .

Investigation of Differences between Semiconductor laser and Solid-State Laser: Applications in Dentistry and Tissue Repair

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ABSTRACT

Objective: The objective of the current systematic review and meta-analysis was to compare the effectiveness and applications of semi-conductor and solid-state lasers in the field of applied physics, particularly in the context of medical applications such as wound healing, tissue repair, and dental treatments. ***Methods:*** A thorough search was done in scientific databases like PubMed, IEEE Xplore, ScienceDirect, and Google Scholar. We conducted a search on articles and included only the articles in English between 2010 and 2023. The keywords used for the search included “semiconductor laser OR solid-state laser" AND "applications OR effectiveness" AND "dentistry OR tissue repair OR inflammation OR ulcer." One hundred and ninety seven articles were initially identified, and based on the inclusion and exclusion criteria, 14 were finally included in this review. ***Results:*** The study included 14 articles from 2008 to 2021, with a focus on controlled trials, case reports, clinical studies, comparative studies, and *in vitro* comparative studies. A meta-analysis was performed to analyze the data. The findings of the review suggest that both semiconductor and solid-state lasers have shown efficacy in various medical applications. The quality of the studies included ranged from moderate to high. Both semiconductor and solid-state lasers showed significant influence in clinical medicine. However, in the case of wound healing, solid-state lasers showed superiority.***Conclusion:*** The use of both semi-conductor and solid-state lasers in medical applications, particularly in dentistry and tissue repair has been demonstrated to be effective, but additional studies are needed to determine the optimal laser type for particular applications. Additionally, standardization of study design and outcome reporting is necessary to improve the quality of evidence in this field.

Keywords: laser therapy; semiconductor laser; solid-state laser; application; dentistry; tissue repair

INTRODUCTION

Lasers have been extensively used in medical physics for diagnosis, therapy, and surgery due to their ability to deliver precise and controlled energy to the target tissues. While historically, the predominant focus has been on semiconductor and solid-state lasers in medical physics, this initial emphasis, though significant, merely scratches the surface of the extensive landscape of laser technologies applied in medical contexts. Two common types of lasers used in medical physics are semiconductor lasers and solid-state lasers. Although both types of lasers are used for similar medical applications, there are differences in their physical properties, such as their emission wavelength, coherence, and power output, which can affect their effectiveness in various medical applications.[1]

The laser application is hailed as a crucial step forward in technical development. Due to their therapeutic effects and their tissue biostimulation capacity, they are utilized as an adjuvant. The scope of laser applications in medicine extends far beyond the conventional understanding limited to semiconductor and solid-state lasers. The literature reveals a diverse array of laser types employed in medical contexts, including an expansive range such as gas lasers (He-Ne, argon ion, carbon dioxide etc.) tunable lasers utilizing various active media like semiconductors, solid-state crystals, dyes, and gaseous mixtures, among others.[2] This wide-ranging diversity of lasers has significantly broadened the spectrum of biomedical applications, revolutionizing diagnostics, surgeries, therapeutic interventions, and research methodologies. Therapeutic

responses and cellular effects caused by photo-chemical, electrical, and energetic reactions are enhanced by low-level laser applications in the regions of red and near-infrared spectrums.[3]
Semiconductor lasers, which are also called diode lasers, are smaller, lighter, and cheaper than solid-state lasers. The lasers generate light within the range of visible to near-infrared wavelengths. This light is absorbed by chromophores present in the body's tissues, causing several biological effects such as enhanced circulation, alleviation of pain, and tissue restoration. Low-level laser therapy is a non-invasive and low-risk treatment method for several conditions like musculoskeletal disorders, neuropathic pain, and wound healing. Semiconductor lasers are frequently utilized in this therapy.[4] On the other hand, solid-state lasers are generally bigger, more intricate, and pricier compared to semiconductor lasers. These lasers emit light in a narrow range of wavelengths, resulting in high coherence and power output, making them ideal for surgical applications such as cutting, ablation, and coagulation of tissues. Solid-state lasers are commonly used in ophthalmology, dermatology, and dentistry, where high precision and accuracy are required.[5,6]
Even though they are different in these ways, both types of lasers have been shown to be useful in different medical settings. But there are ongoing efforts to improve their performance and find more ways to use them in medicine. For example, recent studies examined semiconductor laser applications in cancer therapy, where their ability to selectively target cancer cells while leaving healthy tissues alone has shown promising results.[7] Additionally, research incorporating solid-state lasers with imaging techniques such as optical coherence tomography (OCT) has demonstrated improved surgical accuracy and reduced complications.[8]

In addition to their medical applications, the research and development of medical devices and systems, such as optical sensors and spectroscopy also uses semiconductor and solid-state lasers. Semiconductor lasers, for instance, have been employed in OCT, a non-invasive imaging method that delivers high-resolution images of tissues and structures within the body. OCT has been used in various medical applications, such as ophthalmology, cardiology, and oncology.[9] Solid-state lasers have also been used in spectroscopy, which is a technique for analyzing the chemical composition of tissues and fluids based on their interaction with light. Spectroscopy has been used in various medical applications, such as cancer diagnosis and monitoring.[10]

Our objective was to conduct a systematic review and meta-analysis of the existing literature to evaluate the effectiveness of semiconductor and solid-state lasers and identify the superior one for various applications. The optical gain and coherence mechanisms of these lasers play a critical role in determining their effectiveness in different medical applications.

Print ISSN 2710-0952 Electronic ISSN 2790-1254

METHODS

Study design

The present systematic review and meta-analysis were carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines. Moreover, the study adhered to the Population, Intervention, Control, and Outcomes (PICO) criteria. The PICO statement of the current study is as follows: P: exploring differences between semiconductor and solid-state lasers; I: using semiconductor and solid-state lasers in medical settings; C: comparing effectiveness of semiconductor and solid-state lasers; O: to identify the superior laser for medical use. Our current study aims to analyze the applications of semiconductor and solid-state lasers in the field of medicine, particularly focusing on dentistry and tissue repair and compare the outcomes between them, with further discussion on their optical gain and coherence mechanisms.

Inclusion and exclusion criteria

The articles meeting all of the following criteria were included in this study: (1) comparative studies; (2) prospective and retrospective analysis; (3) clinical studies involving human participants; (4) studies using semi-conductor lasers or solid-state lasers; (5) studies published from 2008 to 2023; (5) *in vitro* analysis; and (6) original research articles with full-text in English. We excluded articles on studies that met any of the following criteria: (1) studies that did not report outcomes based on the lasers used; (2) systematic reviews and meta-analyses; (3) studies published before 2007; (4) studies published in languages other than English; (5) studies with small sample sizes—studies with patients fewer than five in number; and (6) theoretical reports.

Literature search strategy

This study included only full-text articles published in English. The articles published between January 2008 and March 2023 were searched in the following databases: American Physical Society (APS) Journals, INSPEC Archive, iNSPIRE HEP Database, Scitation, PubMed, PubMed Central, Cochrane databases, Google Scholar, MEDLINE, EMBASE, and Web of Sciences databases. The search terms and strings used for the analysis were "semiconductor laser OR solid-state laser" AND "applications OR effectiveness" AND "medicine OR clinical field" and the string was later modified to focus on specific areas as follows: "semiconductor laser OR solid-state laser" AND "applications OR effectiveness" AND "dentistry OR tissue repair OR inflammation OR ulcer." To gather additional relevant studies, we manually searched the reference lists of the retrieved studies and related reviews. This process was repeated until no further articles could be identified.

Study selection and data extraction

Following the preliminary screening, two researchers individually examined the full text of the literature that met the inclusion criteria. In case of any disagreement, a third researcher was consulted for assessment. Basic and significant data such as the article type, authors, publication year, type of laser used, applications of the laser used, advantages of the used laser, limitations of the used laser, primary outcomes of the study, limitations of the included study, and future directions (if provided) were collected for each article.

Literature quality evaluation

The evaluation of the quality of all studies included in the analysis was performed using the Robivis' (ROB 2.0) assessment tool to assess the risk of bias. Two researchers independently reviewed the selected articles and scored them according to the aforementioned criteria. If there was any discrepancy, a third researcher was consulted for their input. The Jadad scale was employed to assess the quality of the included articles, which focused on determining whether the study was appropriate, if the lasers were adequately described, and if there was a record of dropouts in each study. Each question was assigned a score of "yes" (1 point) or "no" (0 points). The final score was used to categorize the study as low quality (0 to 2 points), moderate quality (3 points), or high quality (4 to 5 points).

Statistical analysis

The statistical analysis was conducted using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). The odds ratio (OR), which is a measure of incidence rate, was calculated by analyzing dichotomous variables, and the interval estimation was reported as a 95% confidence interval (CI). The size of the effect was calculated as the standardized mean deviation. The odds ratio for efficiency and advantages of semi-conductor and solid-state lasers was calculated, and a forest plot was created in Microsoft Excel to represent the overall efficiency of semi-conductor and solid-state lasers in the field of medical physics.

RESULTS

Literature selection

A total of 197 articles were obtained from the APS, INSPEC Archive, iNSPIRE HEP Database, Scitation, PubMed, PubMed Central, Cochrane databases, Google Scholar, MEDLINE, EMBASE, and Web of Sciences databases and by manual search. One hundred and twenty-one articles were excluded in the first screening based on their titles and abstracts as they were non-English abstracts or texts, poster and oral presentations, systematic reviews and meta-analyses, or had no full-text, relevant data, complete laser characteristics, or outcomes. Following the last screening of all gathered articles, 14 original full-text articles that fulfilled all the inclusion criteria were included in the study. The PRISMA chart of the study, which provides detailed data on literature collection and screening, is shown in **Figure 1.** Among the 14 included articles, two were randomized controlled trials, two were case reports, four were clinical studies, and six were comparative studies. The included studied discussed the use of

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Iraqi Journal of Humanitarian, Social and Scientific Research
Print ISSN 2710-0952 Electronic ISSN 2790-1254

lasers in various medical applications, particularly in the context of wound healing, tissue repair, and dental treatments. **Table 1** shows the specific laser characteristics reported in all the studies included in the analysis.

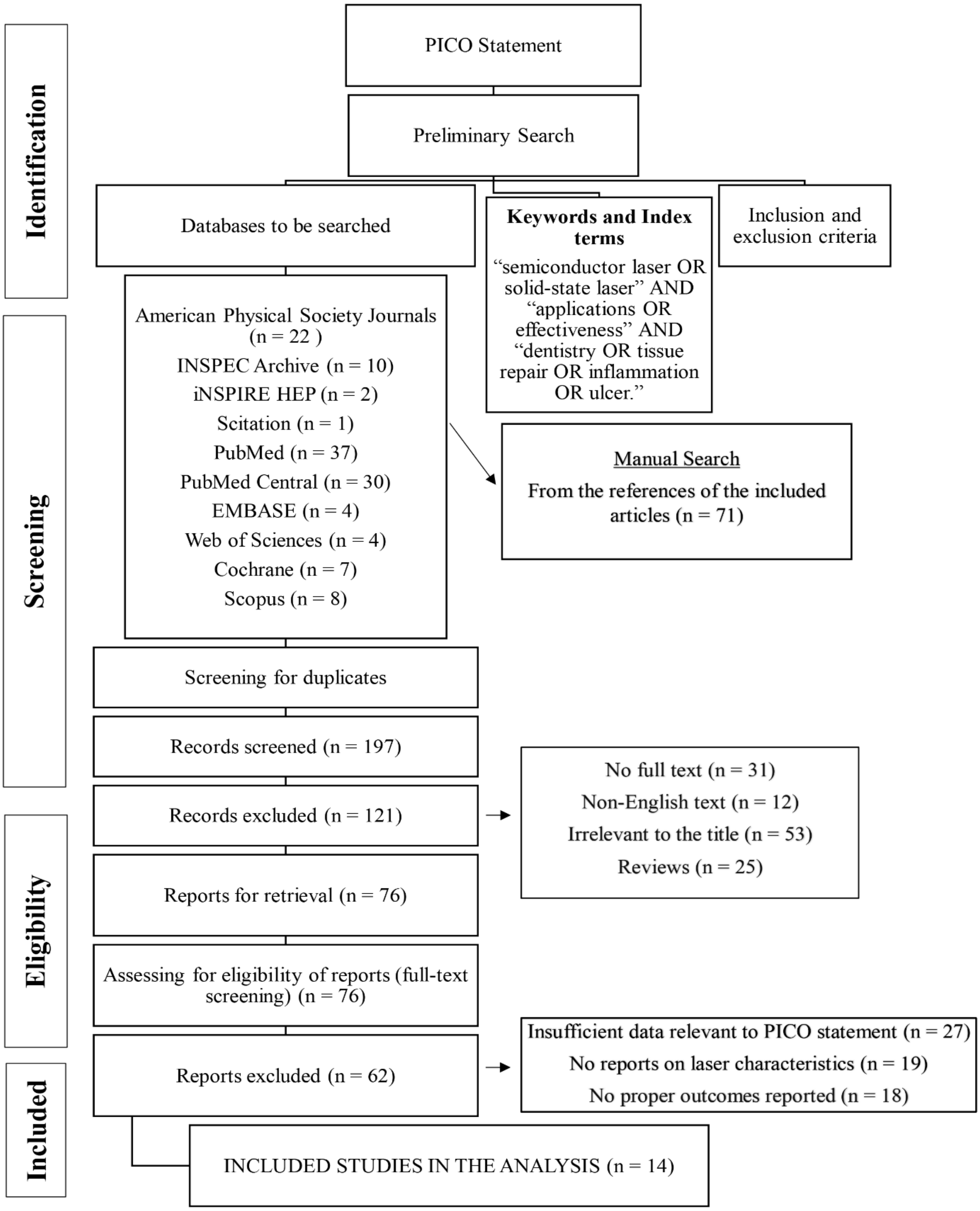

Fig. 1 PRISMA chart of the study design

Table 1 Characteristics of Lasers

S.	LASER	LASER CHARACTERISTICS	References

NO	TYPE		
1.	GaAs diode	Wavelength: 904 nm; Output power: 0.005 W; Mode: Continuous; Energy: 3 (2 × 1.5) J	Salman et al.[11]
2.	Nd: YAG laser	Wavelength: 1064 nm; Output power: 2 W; Mode: Pulsed; Energy: 240-360 J	Tezel et al.[12]
3.	CO_2 and GaAlAs diode lasers	*CO2 laser:* Wavelength: 10.6 μm; Beam diameter: 0.6 mm; Pulse duration: 15 ms; *Semiconductor laser:* Wavelength: 809 nm; Beam diameter: 0.6 mm; Pulse duration: 30 ms	González-Rodríguez et al.[13]
4.	Diode laser class IV and Ezlase diode laser	Wavelength: 810 nm and 940 nm; Output power: 3.5 W and 1.5 W respectively; Mode: Continuous wave	Azma and Safavi [14]
5.	Nd:YAG laser	Wavelength: 1064 nm; Core diameter: 200 μm; Pulse duration: 100 μs	Kanumuru and Subbaiah [15]
6.	Nd:YAG laser	Wavelength: 1064 nm; Energy: 50 mJ; Frequency: 10 Hz; Power: 0.5 W	Gkogkos et al.[16]
7.	Ga-Al-As laser	Wavelength: 810 nm; Energy density: 4 J/cm2	Fekrazad et al.[17]
8.	Nd: YAG and GaAlAs lasers	*Nd:YAG:* Output power: 1 W; Frequency: 10 Hz *GaAlAs*: Output power: 40 mW; Energy: 4 J/cm2; and 0.028 cm2	Soares et al.[18]
9.	Erbium: YAG laser	Wavelength: 2940 nm; Energy: 3.2 J/cm2; Frequency: 3 Hz	Alcolea et al.[19]
10.	InGaAIP laser	Wavelength: 660 nm; Output power: 100 mW; Energy density: 2 J/cm2; Frequency: 10 Hz	Ruh et al.[20]
11.	Nd: YAG and GaAlAs lasers	*Nd:YAG:* Wavelength: 1064 nm *GaAlAs:* Wavelength: 830 nm Er:YAG: 2940 nm Energy: 3.2 J/cm2; Frequency: 3 Hz	Mahran [21]
12.	InGAsP laser	Wavelength: 655 nm; Energy: 5 J/cm2; Frequency: Not reported	Laky et al.[22]
13.	Diode laser	Wavelength: 810 nm; Mode: Contact pulsating wave mode; Output power: 0.1 W; Frequency: Not reported	Habash and Jayash [23]
14.	Nd:YAG laser	Wavelength: 1064 nm; Energy: 8 J/cm2; Frequency: Not reported	de Filippis et al.[24]

Literature Quality

The Jadad scale scores indicated that the quality of the studies ranged from moderate to high, and no studies with low quality were identified (**Table 2**). Among the 14 included articles, six studies had moderate quality[13,16,17,21,24], and eight had high quality.[11,12,14,15,19-23]

Table 2 Quality of the included studies according to the Jadad scale scores

Jadad scale	1. Did the study include human participants?	2. Did the study used appropriate lasers?	3. Did the study reported the outcomes clearly?	4. Has the study provided details on characteristics of laser used?	5. Was the study included free from limitations?	Results	Quality of the study
Salman et al.[11]	1	1	1	1	1	5	High
Tezel et al.[12]	1	1	1	1	1	5	High
González-Rodríguez et al.[13]	0	1	1	1	0	3	Moderate
Azma and Safavi[14]	1	1	1	1	0	4	High
Kanumuru and Subbaiah[15]	1	1	1	1	1	5	High
Gkogkos et al.[16]	0	1	1	1	0	3	Moderate
Fekrazad et al.[17]	0	1	1	1	0	3	Moderate
Soares et al.[18]	1	1	1	0	1	4	High
Alcolea et al.[19]	1	1	1	1	1	5	High
Ruh et al.[20]	1	1	1	1	0	4	High
Mahran	0	1	1	1	0	3	Moder

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[21]							ate
Laky et al.[22]	1	1	1	1	0	4	High
Habash and Jayash[23]	1	1	1	1	1	5	High
de Filippis et al.[24]	0	1	1	1	0	3	Moderate

Footnotes: 0 – yes; 1 – no

Risk of bias

Fig. 2 and 3 show the variables that are used in the plot and summary of the risk of bias assessment.

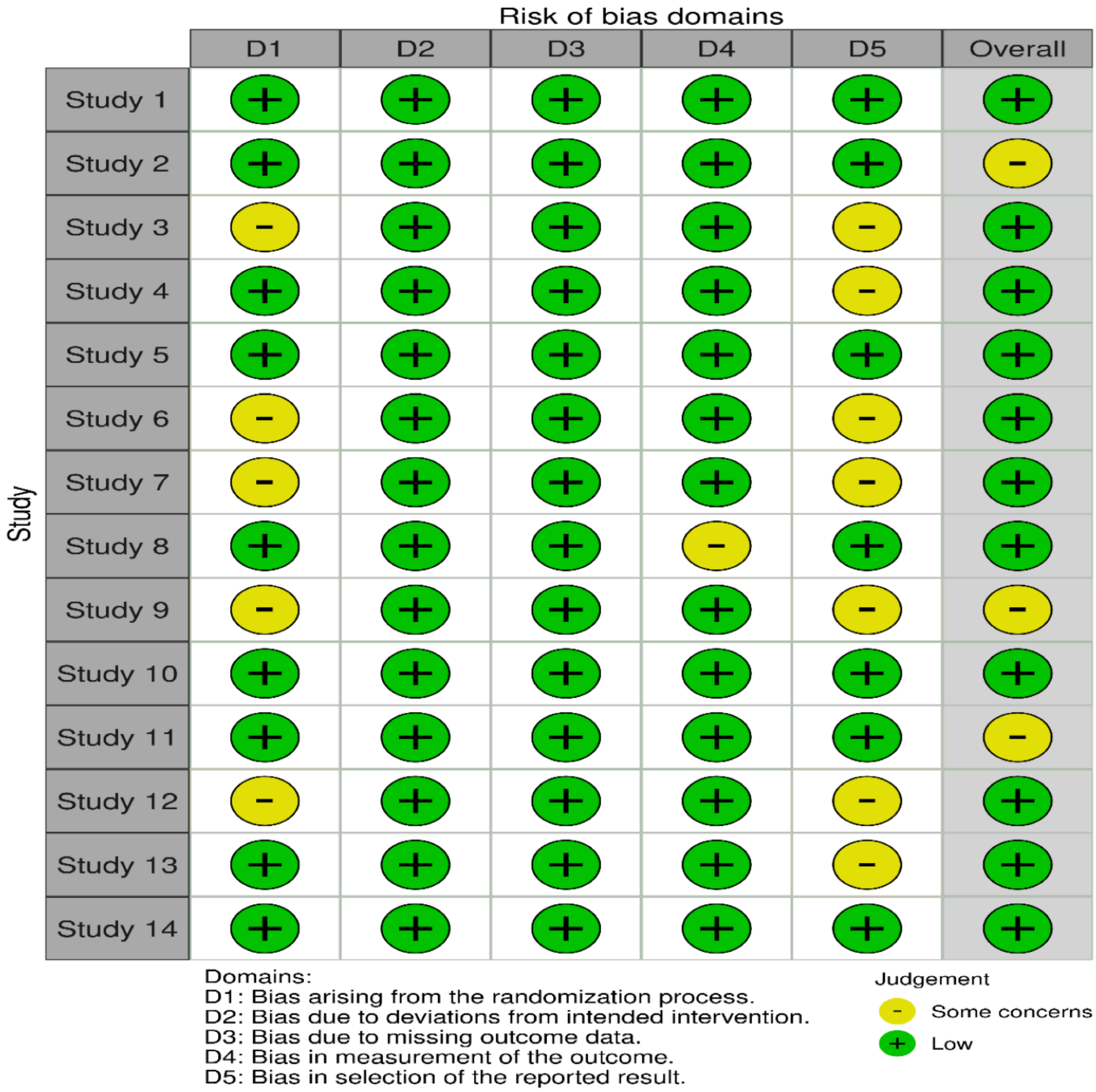

Fig. 2 Risk of bias assessment plot

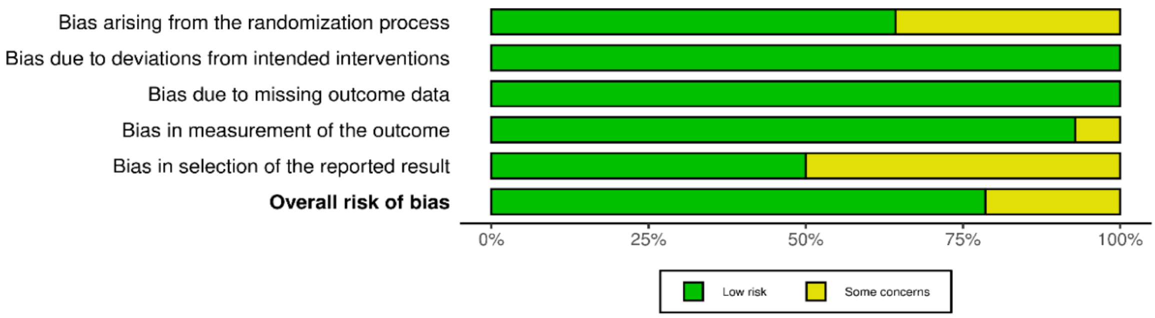

Fig. 3 Summery of the risk of bias assessment

Meta-analysis

Seven articles were excluded from the meta-analysis[12,13,15-17,23,24] due to their nature of the study. A meta-analysis was performed for nine studies. The efficiency in terms of clinical fields indicated that solid-state lasers are more efficient in wound healing than semi-conductor lasers, whereas semi-conductor lasers showed dominance in dentistry fields. The odds ratios between studies on the efficiency rates of semiconductor and solid-state lasers were found to be 10.7 and 2.36, respectively. **Table 3** shows the confidence interval values of semiconductor and solid-state lasers in terms of their efficiency in the included studies. **Figure 4** shows the forest plot constructed to represent the efficiency rates of semiconductor and solid-state lasers. **Table 4** shows all the data extracted and applied in this analysis.

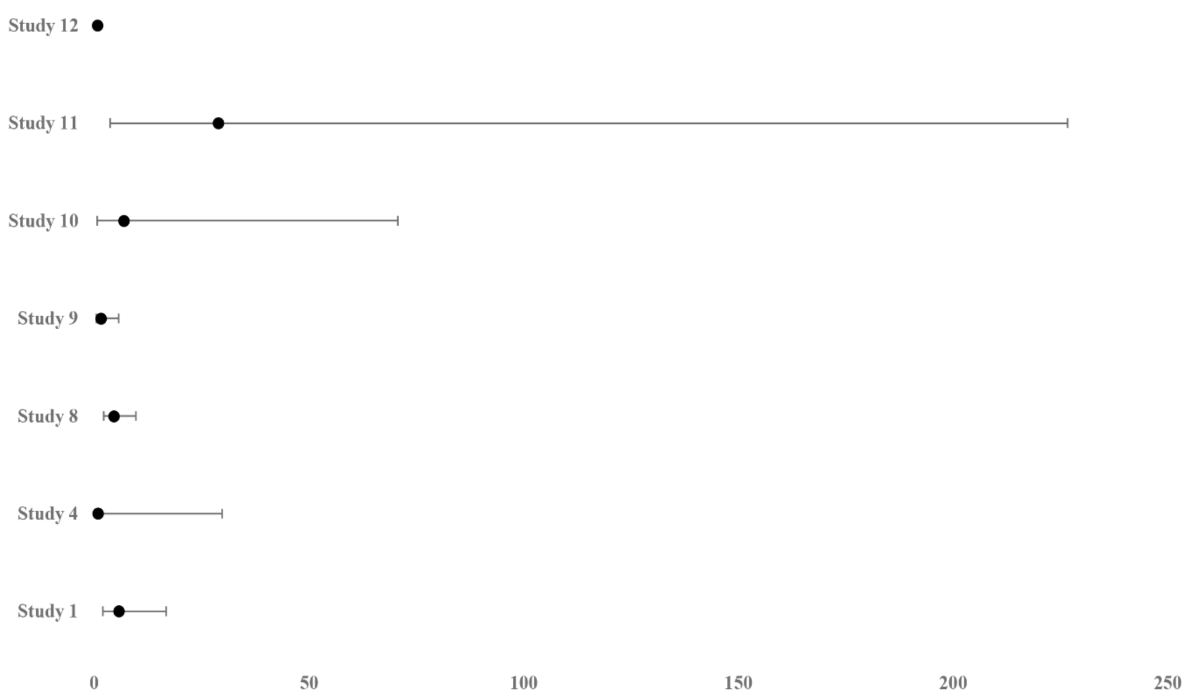

Fig. 4 A forest plot constructed to represent the efficiency rates of semiconductor and solid-state lasers

Table 3 Confidence interval values of semiconductor and solid-state lasers

Study Name	Odds Ratio	95% Confidence Interval (Lower Limit)	95% Confidence Interval (Upper Limit)
Study 1	5.8	2.006448	16.76595
Study 4	1	0.033547	29.80927
Study 10	7	0.692623	70.74556
Study 11	29	3.708238	226.7924
Study 8	4.636364	2.210753	9.723326
Study 9	1.666667	0.488798	5.682878
Study 12	0.8	0.74	0.88

Table 4 Data extraction of the study

S. NO	AUTHOR	PUBLICATION YEAR	ARTICLE TYPE	OBJECTIVES	LASER TYPE	APPLICATION FIELD	ADVANTAGES	LIMITATIONS	OUTCOME OF THE STUDY
1.	Salman et al.[11]	2008	Controlled trial	Examine the impact of laser therapy on wound healing.	Semiconductor laser	Tissue repair	NR	NR	No significant wound healing capacity was observed.
2.	Tezel et al.[12]	2009	Controlled trial	Compare the efficacy of Nd:YAG laser with	Solid-state laser	Applied physics – Medical Field	Patients had better acceptance, shorter treatme	No significant limitations reported.	Nd:YAG laser had better patient accept

				medication.			nt times, and lower rates of pain and post-treatment adverse events.		ance, shorter treatment time, and lower rates of pain and post-treatment adverse events.
3.	González-Rodríguez et al.[13]	2011	Comparative Study	Compare the effects of CO_2 and semiconductor lasers on dental enamel and pulp temperature, and evaluate enamel fluoride uptake.	Semiconductor laser	Dentistry	Greater fluoride uptake on enamel (89±18 mg/l) was observed, along with a lesser alteration of the enamel surface and a greater pulp safety.	The critical limit of 5.5°C is exceeded with the use of semiconductor laser at 7 W, ruling out its use in clinical practice.	Efficiency was higher and pulp safety was higher in semiconductor lasers than CO_2 lasers.

4.	Azma and Safavi[14]	2013	Case Report	Assess the safety and effectiveness of diode lasers.	Semiconductor laser	Dentistry	A definite incision of lesion and hemostasis of surface was achieved.	Small sample size	Semiconductor laser could be used as a modality for oral soft tissue surgery.
5.	Kanumuru and Subbaiah[15]	2014	Clinical study	Evaluate the bactericidal effects of Ca(OH)2, 810 nm diode, 980 nm diode, and Nd:YAG lasers on *E. faecalis* in root canal dentin.	Solid-state laser	Dentistry	The teeth irradiated with the Nd:YAG laser had significantly higher bacterial reduction than all the other groups.	No significant limitations reported.	Nd:YAG laser was the most effective to eliminate and disinfect root canals with E. faecalis.
6.	Gkogkos et al.[16]	2015	*In vitro* comparative	Investigate the effects of	Solid-state laser	Dentistry	Laser irradiation promoted	No significant limitations	Nd:YAG laser treatment

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			study	Low-Level Laser Therapy on the proliferation and growth factors' secretion of human gingival fibroblasts.			higher cell proliferation.	reported.	might have induced gingival fibroblasts' proliferation and upregulated the secretion of EGF.
7.	Fekrazad et al.[17]	2016	*In vitro* comparative study	Evaluate the effectiveness of applying cultured autologous bone marrow mesenchymal stem cells with scaffold and low-level laser therap	Semiconductor laser	Tissue repair	Low-level laser therapy improved bone formation.	*In vivo* nature study.	Healing in osteochondral defects was observed with laser therapy.

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				y on repairing articular cartilage defects in rabbits.					
8.	Soares et al.[18]	2016	Clinical study	Compare the efficacy of Nd:YAG laser, GaAlAs laser, and 2% neutral fluoride gel in treating dentinal hypersensitivity.	Semiconductor and solid-state laser	Dentistry	A higher pain reduction rate was observed with lasers.	No significant limitations reported	Laser treatments resulted in significantly greater reductions in pain intensity.
9.	Alcolea et al.[19]	2017	Clinical study	Evaluate the results obtained by treating CLEUs with an Er:YAG	Solid-state laser	Ulcer	Laser irradiation promoted ulcer healing faster and safer, with no morbid	No limitations reported.	This technology offered an effective and safe alternative for treatin

				laser.			ity risk or complications.		g CLEUs.
10	Ruh et al.[20]	2018	Clinical study	Assess the expression of inflammatory and reparative factors (IL6, TNF, VEGF, and TGF) involved in tissue healing under low-level laser therapy.	Semiconductor laser	Tissue repair	Laser irradiation promoted ulcer healing.	Control group was not used.	Low-level laser therapy was a promising healing tool to reduce PU size; after low-level laser therapy, wounds presented improvement in gross appearance, with an increase in factors VEFG and TGF-

									β.
11	Laky et al.[22]	2020	Clinical study	Evaluate the effectiveness of 655 nm InGaAsP diode laser in detecting subgingival calculus in patients with periodontal disease.	Semiconductor laser	Dentistry	The 655 nm InGaAsP diode laser was able to detect subgingival calculus.	*In vivo* nature of the study	A 655 nm diode-laser fluorescence device (Diagnodent) was effective in subgingival calculus detection in periodontal treatment and could possibly enhance non-surgical periodontal therapy.
12	Mahran[21]	2020	Comparative study	Investigate the effectiveness of high and	Semiconductor and solid-state laser	Medicine	More wound contraction and a higher healing	No limitations reported	Solid-state lasers were effective in woun

				low-intensity pulsed lasers on full-thickness wounds in rats and compare their effects.			rate were observed.		d healing.
13	Habash and Jayash [23]	2021	Case Report	Demonstrate the application of a diode laser in removing inflamed tissue and regenerating horizontal bone defects around implants.	Semiconductor laser	Tissue repair	Bone lesion healing was observed.	No limitations reported.	Low-level laser therapy was effective in the treatment of peri-implantitis.
14	de Filippis et al.[25]	2021	*In vitro* comparative study	Analyze the role of solid-state lasers	Solid-state laser	Tissue repair	Wound healing was observed.	*In vitro* nature of the study	Wound healing was observed.

	in the wound healing process.	

Nd:YAG - Neodymium-doped Yttrium Aluminum Garnet; GaAlAs - Gallium Aluminum Arsenide; CLEU – chronic lowe extremity ulcer; Erbium:YAG - Erbium-doped Yttrium Aluminum Garnet; PU – Peptic ulcer; IL-6 - Interleukin-6; TNF - Tumor Necrosis Factor; VEGF - Vascular Endothelial Growth Factor; TGF - Transforming Growth Factor; InGaAsP - Indium Gallium Arsenide Phosphide

DISCUSSION

Our systematic review included 14 studies that all pertain to the use of lasers in various medical applications, particularly in the context of wound healing, tissue repair, and dental treatments. Laser therapy has been extensively studied for its ability to improve wound healing, and several types of lasers have been investigated for various applications in dentistry and medicine. This systematic review was aimed at summarizing the available literature on the impact of laser therapy on various medical applications by comparing the efficacy of semiconductor and solid-state lasers and examining their safety and effectiveness.

In our study, we included five articles on laser therapy for tissue repair.[11,17,20,23,25] The effects of laser therapy on wound healing, including its ability to stimulate tissue repair, reduce inflammation, and promote angiogenesis were analysed in those studies. Among these five studies, four used semiconductor lasers and one used solid-state lasers. Studies have demonstrated that low-level laser therapy can enhance wound healing by promoting fibroblast proliferation and migration, as well as boosting collagen synthesis. Likewise, animal models have shown that diode lasers can improve wound healing by reducing inflammation and promoting angiogenesis. Moreover, the combination of cultured autologous bone marrow mesenchymal stem cells with scaffolds and low-level laser therapy has displayed promising results in repairing articular cartilage defects in rabbits. However, a head-to-head comparison on wound healing between semiconductor and solid-state lasers has shown that solid-state lasers are superior in wound healing.[11,24]

Using the neodymium-doped yttrium aluminum garnet (Nd:YAG) laser has better efficacy than medication in treating venous ulcers by promoting angiogenesis and increasing blood flow to the affected area.[12] Using CO_2 and semiconductor lasers in dental enamel has also been compared, with CO_2 lasers showing greater enamel fluoride uptake, but semiconductor lasers producing less pulp temperature increase, making them safer for use in clinical settings.[13]

Due to their safety and efficacy, diode lasers have gained popularity in the field of dentistry. These lasers have been found to promote wound healing by stimulating fibroblast proliferation, reducing inflammation, and promoting angiogenesis. Furthermore, diode lasers have been employed in treating dentinal hypersensitivity, with comparable effectiveness to that of Nd:YAG and gallium aluminum arsenide (GaAlAs) lasers and 2% neutral fluoride gel.[14,18]
A study by Kanumuru and Subbaiah (2014) investigated the anti-bacterial effects of different lasers on *Enterococcus faecalis* in root canal dentin.[15] The Nd:YAG laser has better efficacy in reducing bacterial counts as well as promoting apical closure in cases of refractory periapical periodontitis. The efficacy of 810 nm and 980 nm diode lasers has been demonstrated in reducing bacterial counts and promoting wound healing in cases of chronic periodontitis. Low-level laser therapy has been reported to affect the expression of various inflammatory and reparative factors related to tissue healing, such as interleukin-6 (IL6), tumor necrosis factor (TNF), vascular endothelial growth factor (VEGF), and transforming growth factor (TGF). Low-level laser therapy has been shown to enhance the expression of VEGF and TGF, which contributes to increased angiogenesis and collagen synthesis, while suppressing the expression of inflammatory cytokines.[20]
Many studies have looked into the use of lasers in various dental procedures, such as the treatment of hypersensitive dentin and the removal of caries.The use of an Erbium:YAG (Er:YAG) laser is effective in the treatment of caries and chronic lower extremity ulcer (CLEUs) with minimal thermal damage to surrounding tissues.[19] Two studies[19,20] conducted studies using lasers for the treatment of ulcers with solid-state and semiconductor lasers, respectively. However, both types of lasers showed a positive response in terms of healing ulcers. Among the 14 studies, six discussed the influence of lasers in the dentistry field[13-16,18,22] of which three used semi-conductor lasers, two used solid-state lasers, and one study used both. However, all the studies reported significantly higher positive effects for both lasers.
Our research has few limitations. First, the number of available studies comparing the solid-state and semiconductor lasers is small, and hence, they could not be discussed elaborately. Second, we have included *in vitro* and animal studies as well; hence, the risk of bias in assessment cannot be ruled out. Additionally, it's important to note that excluding non-English articles is also a limitation, potentially restricting the diversity of perspectives and findings in our review. Despite these limitations, we have compared semiconductor and solid-state lasers in different medicinal fields and provided an elaborate review on the same. However, more research on comparing semiconductor and solid-state lasers is warranted.

Conclusion

Laser therapy has been extensively studied for its ability to promote wound healing, with different types of lasers showing varying efficacy and safety profiles. While more research is needed to fully understand the mechanisms underlying the therapeutic effects of laser therapy, the evidence suggests that it is a promising modality for improving wound healing and promoting tissue repair, irrespective of whether it is a semiconductor or solid-state laser. The use of lasers in dentistry has also shown promising results, particularly in the treatment of dentinal hypersensitivity and caries removal. Further research is necessary to fully assess their effectiveness and safety in clinical settings.

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