

Review Article

Effect of laser treatment on outcomes of tooth replantation – A systematic review



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المخلص

أهداف البحث: على مدى السنوات القليلة الماضية، حققت العديد من الدراسات تأثير العلاج بالليزر على إعادة زرع الأسنان المخلوعة. تهدف هذه المقالة للتحليل المنتظم وتقييم نتائج وجود هذه الدراسات.

طرق البحث: عن طريق استخدام الكلمات المفتاحية الأساسية "الليزر" و"الأسنان" و"إعادة زرع الأسنان"، تم إجراء بحث إلكتروني عبر قواعد بيانات بوب ميد وإمبيز، وشبكة المعرفة، والباحث العلمي لجوجل بواسطة باحثين. تم استبعاد أي دراسات لا تفي بالمعايير الضم لدينا. وكان سؤال الدراسة هو: هل العلاج بالليزر يؤثر على نتائج إعادة زراعة الأسنان المخلوعة؟

النتائج: تم أدرج تسع دراسات وتقييمها في هذه المراجعة. في معظم الدراسات، كان الليزر له نتائج إيجابية على منع ذوبان الجذر وتعزيز تجديد الأنسجة المحيطة باللثة. ومع ذلك، تم إعطاء ثلاث دراسات فقط جودة "متوسطة"، في حين تم تقييم ست دراسات بأنها ذات جودة "منخفضة".

الاستنتاجات: قد تقلل إشعاعات الليزر من ذوبان الجذر ويعطي أفضلية في تجديد الأنسجة المحيطة باللثة بعد إعادة زرع السن المخلوع. ومع ذلك، هناك حاجة إلى مزيد من الدراسات طويلة الأجل على الحيوان والبشر جيدة التصميم قبل استخدام الليزر سريريا لتحسين نتائج الأسنان المزروعة.

الكلمات المفتاحية: صدمة؛ سقوط الس؛ إعادة الزرع؛ تجديد؛ ليزر

Abstract

Objectives: Over the last few years, several studies have investigated the effect of laser treatment on the replantation of avulsed teeth. We conducted this study to systematically analyse and assess the outcomes and quality of these studies.

Methods: Using the keywords 'laser', 'tooth', and 'replantation', two investigators conducted an electronic search of the PubMed, MEDLINE, Embase, ISI Web of Knowledge and Google Scholar databases. Any studies not meeting the inclusion criteria were excluded. The focused question was 'Does laser treatment influence the outcomes of tooth replantation?'

Results: Nine studies were included and assessed in this review. In the majority of the selected studies, laser treatment had a positive outcome on preventing root resorption and in promoting periodontal regeneration. However, only three studies were given a quality score of 'medium', while six were marked as 'low'.

Conclusion: Laser irradiation may reduce root resorption and favour periodontal regeneration following replantation of the avulsed tooth. However, more well-designed long-term animal and human studies are needed before lasers can be used clinically to improve the outcomes for replanted teeth.

Keywords: Laser; Regeneration; Replantation; Tooth avulsion; Trauma

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Introduction

Tooth avulsion involves the complete displacement of the tooth from its socket due to trauma.¹ Complete avulsion of teeth accounts for 0.5–16% of all types of dentoalveolar injuries.² Immediate replantation of the tooth is the main treatment option for avulsed teeth.³ However, a prolonged extraoral period, contamination, and dehydration of the root have adverse effects on the outcome of tooth replantation.⁴ Additionally, disruption of the neurovascular supply and periradicular periodontal tissues lead to necrosis of the dental pulp.⁵ These pathogenic processes may lead to root resorption and destruction of periapical tissues, leading to tooth loss. If not replanted within 15 min of avulsion, the long-term prognosis of tooth replantation decreases significantly.³ If immediate replantation is not possible, storing the avulsed tooth in a suitable medium, such as milk, saline, or Hank's balanced salt solution, has been advocated.⁶ Prior to replantation, root canal treatment, along with placement of intracanal medications, such as calcium hydroxide and mineral trioxide aggregate, and surface treatment with reagents, such as sodium fluoride, may be performed to minimize the chances of root resorption.^{7,8} However, even with the provision of available treatment modalities, teeth may still be lost to resorption as early as 4–6 years following replantation.⁹

Laser (an acronym for light amplification by stimulated emission of radiation) involves the production of amplified light by the stimulation of photons via interaction with excited electrons. Laser therapy has found a range of applications in dentistry.¹⁰ Lasers have been used for cavity preparation, oral soft tissue surgical procedures, and periodontal therapy. Similarly, animal studies have indicated that laser treatment of root surfaces and periodontal bone may improve the outcomes of tooth replantation^{11,12} by enhancing cellular proliferation,¹³ promoting angiogenic factors,¹⁴ and down-regulating pro-inflammatory factors.¹⁵ On the other hand, some animal studies indicate that laser therapy may not have a significant beneficial effect on the outcomes of tooth replantation.^{16,17} The purpose of this review is to systematically analyse studies in which lasers have been used to minimize external root resorption and bone loss following tooth replantation. In addition, general characteristics, laser parameters, outcomes, and limitations are discussed.

Materials and Methods

Focused question

This systematic review was conducted according to the Preferred Reported Items for Systematic Review and Meta-

Analysis (PRISMA) guidelines.¹⁸ The focused question of ‘Does laser treatment influence the outcomes of tooth replantation?’ was formulated using the Participants Intervention Control and Outcomes protocol.

Eligibility criteria

Studies possessing the following attributes were considered for inclusion in the review: 1) original articles, 2) articles written in English, 3) studies on replantation of teeth, 4) laser therapy in test group, 5) animal studies, and 6) randomized clinical trials. Reviews, case reports, letters to the editor, studies published in a language other than English, and commentaries were excluded.

Search methodology

Using the keywords (“lasers”[MeSH Terms] OR “lasers”[All Fields] OR “laser”[All Fields]) AND (“tooth”[MeSH Terms] OR “tooth”[All Fields]) AND (“replantation”[MeSH Terms] OR “replantation”[All Fields]), an electronic search of the PubMed/MEDLINE, Embase, ISI Web of Knowledge, and Google Scholar databases was conducted by two investigators, S.N. and Z.K. Both investigators conducted the search independently and any disagreements were resolved via discussion. The titles and abstracts of the articles identified in the primary search were read and any non-relevant studies were excluded. Additionally, the reference lists of the articles were scanned for any additional studies matching our inclusion criteria. The full texts of relevant articles were read to further refine the search results. A PRISMA flow diagram for the search methodology used is shown in [Figure 1](#).

Quality assessment of studies

The quality assessment of included studies were assessed using a modified version of the quality scales developed by Antzaic et al.¹⁹ and Jadad et al.²⁰ The size of included samples, statistical calculation of sample size, statistics of the results, error method analysis, blinding, and reporting of lost subjects during each study were considered to assign a score of high, medium, or low to each study. Due to the heterogeneity of the studies included in the present review, it was not possible to conduct a meta-analysis.

Results

Search results

The primary search identified 55 articles. After the exclusion of 43 articles based on their titles and abstracts, the full texts of 12 articles were read to exclude studies not fulfilling our eligibility criteria. Three studies^{21–23} were excluded and nine studies^{11,12,16,17,24–28} were included in the systematic analysis. Excluded articles, along with reasons for exclusion, are listed in [Table 1](#) while included studies, along with their characteristics, outcomes, and quality score are listed in [Tables 2–4](#). The inter-rater reliability (kappa) value was 0.825.

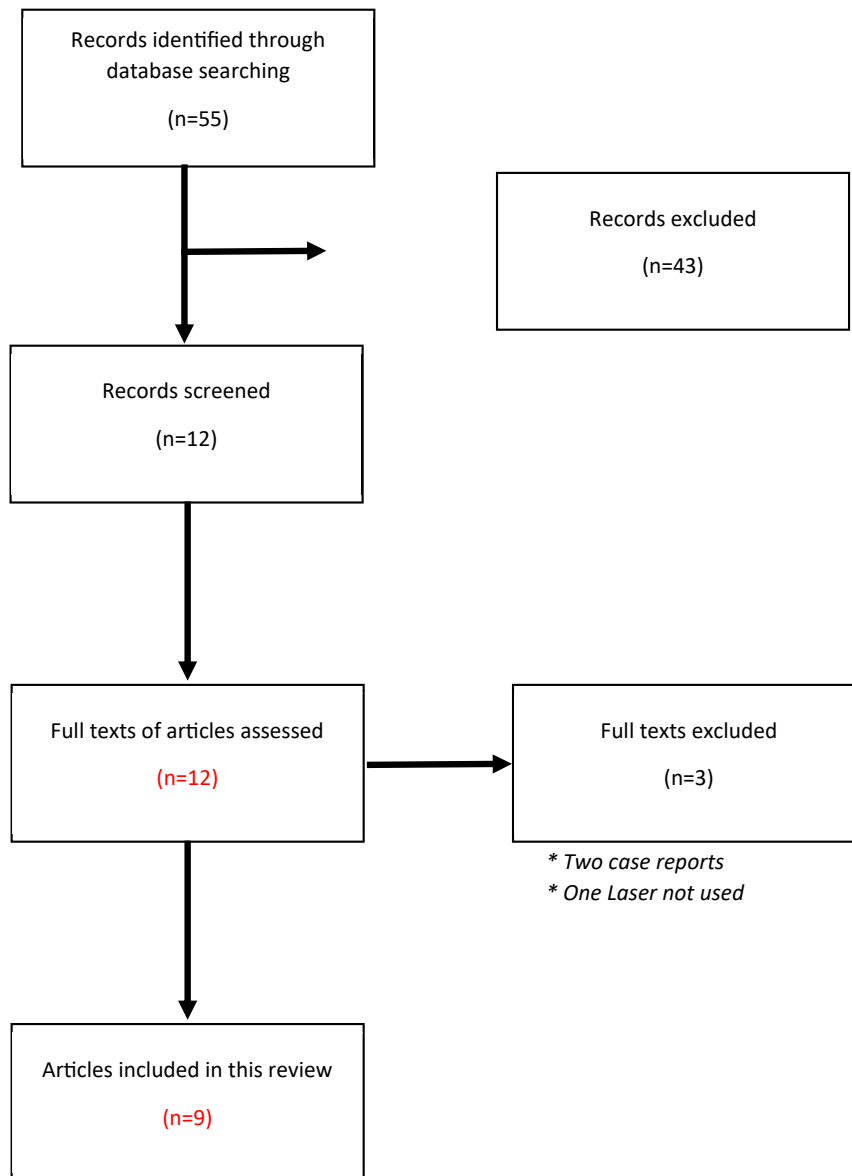


Figure 1: PRISMA flow diagram for the literature search performed in this study.

General characteristics of included studies

All studies included were animal studies.^{11,12,16,17,24–28} One study replanted dog premolars.¹⁷ In seven studies, rat incisors were replanted^{11,12,16,24,25,27,28} and human roots were replanted subcutaneously into rats in another study.²⁶ The number of animals included in the studies ranged from 6 to 72.^{11,12,16,17,24–28} Drying (extraoral) time ranged from

5 min to 72 h.^{11,12,16,17,24–28} The duration of studies ranged from 15 days to 12 weeks.^{11,12,16,17,24–28} Friedman et al. compared the efficacy of laser treatment on replanted teeth with plaque inoculated in the pulp and those with endodontic treatment carried out.¹⁷ Hamaoka et al.²⁶ and Carvalho et al.²⁵ compared the efficacy of laser treatment with sodium fluoride (NaF) treatment. In the studies by Saito et al.¹⁶ and Vilela et al.,²⁴ laser treatment following storage in saline was compared with saline treatment alone. De Carvalho et al. compared the efficacy of laser treatment of the extraction socket and mucosae with no extraoral treatment and storage in milk.¹¹ In the studies by Matos et al.,^{12,28} laser treatment with and without storage in cow's milk was compared with storage in cow's milk, soy milk, and in a paper napkin. Finally, in the study by Carvalho et al.,²⁷ laser treatment with and without fibroblast growth factor (FGF) was compared with immediate replantation and replantation after an extraoral

Table 1: List of studies excluded from this review and the reasons for exclusion.

Study	Reason for exclusion
Gupta et al. ²²	Case report
Rungvechvuttivittaya et al. ²¹	Lasers not used
Lu et al. ²³	Case report

Table 2: General characteristics and main outcomes of the included studies. FGF: fibroblast growth factor; UHT: Ultra-high temperature pasteurization.

Study (author and year)	Animals (n)	Replanted teeth/ roots (n)	Treatment groups & number of teeth/root (n)	Extra-oral drying time in treatment groups	Duration of study	Main outcome(s)
Friedman et al., 1998 ¹⁷	2 dogs	6 dog premolars/32 roots replanted	I: Saline + laser (12 roots; dentine defect) II: Saline (12 roots; dentine defect) III: Saline + laser (4 roots; RCT, dentine defect) IV: Saline (4 roots; RCT, dentine defect)	<5 min in all groups	12 weeks	Nd:YAG had insignificant effect on resorption.
Hamaoka et al., 2009 ²⁶	12 rats	48 human roots planted subcutaneously	I: No surface treatment, RCT II: 2.4% NaF, RCT III: Saline, RCT IV: Saline + laser, RCT	I: 3 h II: 3 h III: 72 h IV: 3 h	45 days	Root repair observed only in Nd:YAG treatment group.
Saito et al. 2011 ¹⁶	60 rats	60 incisors	I- III (30): RCT with Ca(OH) ₂ , Saline IV-VI (30): RCT with Ca(OH) ₂ , Saline + laser	I: 4 min II: 30 min III: 40 min IV: 4 min V: 30 min VI: 45 min	60 days	Comparable resorption observed in all groups. Laser treatment did not improve outcomes.
Carvalho et al. 2012 ²⁵	60 rats	60 incisors	I (15): No treatment II (15): 2% NaF III (15): Laser IV (15): Pulsed laser	60 min in all groups	60 days	Significantly less root resorption observed after laser treatment compared to other groups.
Vilela et al. 2012 ²⁴	72 rats	72 incisors	I (36): No treatment II (36): Saline + laser	15 min in all groups	60 days	Significantly less root resorption observed after laser treatment compared to controls.
de Carvalho et al. 2016 ¹¹	60 rats	60 incisors	I (15): No treatment II (15): Milk III (15): Laser at extraction socket once IV (15): Laser at buccal and palatal mucosae, every 48 h	I: 40 min	60 days	Significantly less root resorption observed after laser treatment on extraction socket compared to other groups.
Matos et al. 2016 ¹²	60 rats	60 incisors	I: Paper napkin II: UHT cow milk III: Soymilk IV: No treatment + laser V: Milk + laser VI: Soymilk + laser	45 min in all groups	30 days	Comparable root resorption in all groups.
Carvalho et al. 2017 ²⁷	50 rats	50 incisors	I: Laser, (10) II: FGF (10) III: Laser + FGF (10) IV: No treatment (10) V: No treatment (10)	I-IV: 60 min, V: immediate replant	60 days	Laser treatment (with or without FGF) reduced ankylosis and resorption. Only FGF alone favoured periodontal regeneration.
Matos et al. 2018 ²⁸	20 Wistar rats	20 incisors	I: Paper napkin (5) II: UHT cow milk (5) III: Paper napkin + laser (5) IV: UHT cow milk + laser (5)	I: 45 min II-IV: Not stated	15 days	Laser treatment significantly increased angiogenesis.

Table 3: Laser parameters reported in the included studies.

Study (author, year)	Laser medium	Mode (pulsed/continuous)	Frequency (Hz)	Energy density ($J\ cm^{-2}$)	Energy output	Wavelength	Power output (W)	Power density ($W\ cm^{-2}$)	Irradiation duration/site
Friedman et al., 1998 ¹⁷	Nd:YAG	Pulsed (15/s)	n.d.	n.d.	n.d.	1.06 μ m	0.75 W	n.d.	20s (root)
Hamaoka et al., 2009 ²⁶	Nd:YAG	Pulsed (50 msec)	20	124.34	100 J	1.064 μ m	2 W	n.d.	Root: 10s
Saito et al. 2011 ¹⁶	GaAlAs	Continuous	n.d.	57.14	4 J	660 nm (root); 830 nm (bone)	30 mW (root); 40 mW (bone)	n.d.	Root: 133s; Bone: 100s
Carvalho et al. 2012 ²⁵	GaAlAs	Pulsed & continuous	n.d.	n.d.	n.d.	810 nm	1 W–1.2 W	n.d.	Root: 30s
Vilela et al. 2012 ²⁴	InGaAl	Continuous	n.d.	200	4 J	685 nm	n.d.	2.5	n.d.
de Carvalho et al. 2016 ¹¹	GaAlAs	Continuous	n.d.	Root: 16.8; Mucosa: 4.2; Bone: 4.2	n.d.	780 nm	70 mW	n.d.	Root: 320s; Mucosa: 120s; Bone: 60s
Matos et al. 2016 ¹²	n.d.	Continuous	n.d.	61	1.7 J	808 nm (bone and root); 606 nm (mucosa)	100 mW	3.6	Bone and root: 119s; Mucosa: 34s
Carvalho et al. 2017 ²⁷	Diode	Continuous	n.d.	214.3	45 J	808 \pm 10 nm	1.0 W–1.2 W	214.3	Root: 30s
Matos et al. 2018 ²⁸	GaAlAs	Continuous	n.d.	61	1.7 J	808 nm	100 mW	3.6	Root: 119s

Table 4: Quality assessment results of the included studies.

Study	Blinding	Randomization	Appropriate statistics	Sample size calculation	Loss of animals reported	Appropriate measurement	Method error calculation	Quality of study
Friedman et al., 1998 ¹⁷	No	No	Yes	No	No	Yes	No	Low
Hamaoka et al., 2009 ²⁶	No	Yes	Yes	No	No	No	No	Low
Saito et al. 2011 ¹⁶	Yes	Yes	Yes	No	No	Yes	No	Medium
Carvalho et al. 2012 ²⁵	Yes	No	Yes	No	No	Yes	No	Low
Vilela et al. 2012 ²⁴	Yes	Yes	Yes	No	No	Yes	No	Medium
de Carvalho et al. 2016 ¹¹	No	Yes	Yes	No	No	Yes	No	Low
Matos et al. 2016 ¹²	Yes	Yes	Yes	No	No	Yes	No	Low
Carvalho et al. 2017 ²⁷	Yes	Yes	Yes	No	No	Yes	No	Low
Matos et al. 2018 ²⁸	Yes	Yes	Yes	No	No	Yes	No	Medium

time of 60 min. The general characteristics of the included studies are summarized in [Table 2](#).

Laser parameters of included studies

GaAIs was the laser medium in three studies.^{11,16,28} Two studies used Nd:YAG lasers.^{17,26} In one study, an InGaAl medium was used.²⁴ A diode laser was used in two studies.^{25,27} In one study, the laser medium was not stated.¹² Continuous irradiation was performed in six studies.^{11,12,16,24,27,28} Two studies performed irradiation in the pulsed mode,^{17,26} while one study used both pulsed and continuous modes.²⁵ Only one study stated the laser frequency, which was 20 Hz.²⁶ Energy densities ranged from 4.2 Jcm⁻² to 214 Jcm⁻².^{11,12,16,17,24,26-28} Energy density was not stated in one study.²⁵ Total energy output ranged from 1.7 J to 100 J.^{12,16,24,26-28} Three studies did not state any energy output.^{11,17,25} Wavelengths of the lasers ranged from 660 nm to 1.06 µm.^{11,12,16,17,24-28} Eight studies reported total power outputs ranging from 70 mW to 2 W.^{11,12,16,17,25-28} One study did not report the power output.²⁴ Only four studies reported power densities, which ranged from 2.5 Wcm⁻² to 214.3 Wcm⁻².^{12,24,27,28} The laser irradiation duration ranged from 10 s to 320 s.^{11,12,16,17,25-28} One study did not report the irradiation duration.²⁴ The parameters of the lasers used in the reviewed studies are summarized in [Table 3](#).

General outcomes of included studies

The majority of studies included in this review indicated that laser treatment reduces root resorption.^{11,24-27} In two studies, laser use improved the outcome of replanting endodontically treated teeth,^{16,26} suggesting a synergistic effect of laser treatment and endodontic treatment. In other studies, laser treatment had significantly superior effects on reducing root resorption compared to sodium fluoride treatment alone.^{25,26} One study suggested the angiogenic potential of laser treatment.²⁸ In three studies, laser irradiation did not have a significant effect on the outcomes of tooth replantation.^{12,16,17}

Results of quality assessment

Out of the nine studies assessed, six studies employed blinding.^{12,16,24,25,27,28} In seven studies, randomization of the animal subjects was performed.^{11,12,16,24,26-28} Appropriate statistical tests were performed in all studies.^{12,16,24,25,27,28} None of the studies included a sample size calculation, reported any loss of animals or a method error analysis. Eight studies included an appropriate measure of results.^{11,12,16,17,24,25,27,28} Hence, six studies were assigned a quality score of 'low',^{11,12,17,25-27} and three studies were judged as 'medium'.^{16,24,28} The results of the quality assessment are shown in [Table 4](#).

Discussion

Laser photo modulation has been used widely in a range of biomedical and dental applications in recent years.¹⁰ Prolonged extra-oral drying time, in excess of 15 min, has a

deleterious effect on the outcomes of replantation of avulsed teeth.²⁹ Drying damages periodontal ligament cells and exposes the cementum, leading to inflammation and root resorption.³⁰ The exposed cementum attracts osteoclasts, which resorb the root and surrounding periodontal bone.³¹ Additionally, necrosis of the pulp tissue and bacterial contamination of the pulp and exposed dentin tubules exacerbate the inflammatory and resorptive processes.³² Avulsed teeth that have dried for more than 60 min are highly unlikely to survive replantation, which is the treatment of choice for avulsed teeth.³ Even with the provision of root surface treatments with reagents such as sodium fluoride and non-surgical endodontic treatment, a systematic review of 23 clinical studies by Souza et al. estimated that approximately 89% of replanted teeth undergo resorption,³³ with replacement root resorption being the most common type.

Lasers have been used to promote tissue regeneration in several studies.²⁴⁻²⁸ Studies have proposed several mechanisms by which lasers can promote tissue repair. Low-power lasers have been shown to stimulate osteoblasts to deposit higher amounts of calcium.³⁴ Additionally, laser exposure stimulates a higher deposition of collagen by fibroblasts in skin wounds.³⁵ Similarly, in vivo and clinical studies have shown that lasers promote periodontal regeneration.^{36,37} The studies reviewed in this article indicate that laser irradiation of the root and/or the surrounding tissues may promote periradicular tissue regeneration and minimize root and bone resorption.^{16,17,24-28} The application of high-powered lasers to the roots makes the surfaces homogeneous and seals off dentinal tubules by melting them,²⁷ making them impervious to bacterial infection and osteoclasts. In contrast, laser irradiation of the bone and periodontal tissues disinfects the socket and promotes tissue regeneration.^{28,37} The study by Carvalho et al.²⁷ indicates that laser use may augment the osteogenic effect of FGF-2. Hence, the effects of combining lasers with other guided tissue regeneration biomaterials on the outcomes of replanted teeth should be studied.

More recent studies have observed similar effects while using the low-level laser therapy. Acar et al. have observed that using laser treatment as an adjunct to ultrasound promotes bone regeneration in vivo.³⁸ Furthermore, laser treatment enhanced osseointegration following dental implantation.³⁹ Nevertheless, no clinical trials have been carried out to evaluate the efficacy of lasers in improving tooth replantation outcomes. However, a number of theories have been put forward regarding the mechanism of laser-induced regeneration. It is generally agreed that laser irradiation increases osteogenesis by upregulating the expression of various biomolecules, including osteocalcin (OCN), collagen, runt-related transcription factor 2 (RUNX-2), vascular endothelial growth factor, bone morphogenic proteins, and cyclooxygenase-2.⁴⁰ More recently, in vitro studies have shown that laser irradiation in the femtosecond range induces a higher expression of alkaline phosphatase, RUNX-2, and OCN but has no effect on the proliferation of osteoblasts.⁴¹ Indeed, more research is required to evaluate the mechanism of action and safety of using lasers on avulsed teeth and alveolar bone.

The current review analysed the quality and outcomes of nine studies to ascertain the clinical potential of laser treatment prior to tooth replantation. Although the majority of studies indicate that laser irradiation may promote a more favourable outcome of tooth replantation,^{11,24–27} the authors identified several possible sources of bias that may have influenced the outcomes of the studies.^{17,25–27} None of the studies used a statistically predetermined sample size of animals, method error analysis, or reported any loss of animal subjects during the study.^{12,16,24,25,27,28} Nevertheless, because fewer than 10 publications were included, the authors could not estimate the publication bias. Another avenue that could be explored would be the adjunct effect of laser treatment when used with fluoride treatment. Hence, more well-designed studies should be conducted to investigate the potential of lasers in improving the outcomes of tooth replantation.

Conclusion

After an extensive review of the outcomes, laser phototherapy in the management of replantation of avulsed tooth appears quite promising and may reduce the likelihood of root resorption and ankylosis. Laser irradiation may reduce root resorption and promote periodontal regeneration following replantation of the avulsed tooth. However, due to the heterogeneity and small number of publications, the over effects of laser treatment on replanted teeth and publication bias could not be ascertained. Although the bias assessment was limited due to the limited animal research data, more well-designed long-term animal and human studies are needed before lasers can be used clinically to improve the outcomes of replanted teeth.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

There are no ethical or financial issues, conflicts of interests, or animal experiments related to this research.

Authors contributions

SN and ZKS conceived and designed the study, conducted the research, provided the research materials, and collected and organized data. AAQ & HAA extracted information for the tables in the manuscript, and analysed and interpreted data. ZKS, MSZ, & AAQ worked on qualitative and quantitative assessment under the guidance of all authors. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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