Conservative Dentistry Journal Vol. 12 No. 2 July-December 2022; 68-72

Literature Review

Shock wave enhanced emission photoacoustic streaming (SWEEPS): An alternative to conventional irrigation in endodontic treatment

Jesslyn Jordana[1], Jason Nicholas Tandean[1], Jennifer Fiona Salim[1], Febriastuti Cahyani[2], Galih Sampoerno[2]
[1]Undergraduate Student, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia
[2]Department of Conservative Dentistry, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia

ABSTRACT

Background: *Irrigation is an essential step in root canal treatment (RCT). However, the complex structure of the root canal can limit the penetration of irrigants, causing RCT failure. Shock wave enhanced emission of photoacoustic streaming (SWEEPS) has been developed to improve root canal cleaning by increasing the penetration of irrigants. SWEEPS utilized the Er:YAG laser to generate micropulse, producing bubbles delivered in liquid, causing powerful photodynamic streaming. However, its superiority compared to conventional irrigation remains unclear.* ***Purpose:*** *This study aims to review the available evidence to assess the benefits of SWEEPS over conventional irrigation.* ***Reviews:*** *Article searches were conducted on Pubmed, ScienceDirect, EBSCOhost, and ProQuest using SWEEPS and root canal irrigation as keywords. Articles were included if they aim to assess the benefits of SWEEPS over conventional irrigation in removing smear layer, debris, pulp tissues, or bacteria. A total of 833 articles were initially retrieved from systemic search of literature and 6 articles following inclusion criteria were included in the review. Out of 6 articles, 4 articles suggested that SWEEPS could increase the removal of smear layer, debris, pulp tissues, and bacteria in the root canal compared to conventional irrigation. However, 2 articles found contradictory results, in which SWEEPS and conventional irrigation had similar outcomes in terms of penetration depth and could not completely eradicate biofilm.* ***Conclusion:*** *This review suggests that SWEEPS offers more benefits over conventional irrigation since it can improve the removal of smear layer, debris, pulp tissues, and bacteria in the root canal.*

Keywords: *SWEEPS, laser-activated irrigation, root canal irrigation*

Correspondence: Jesslyn Jordana, Faculty of Dental Medicine, Universitas Airlangga. Jl. Mayjen Prof. Dr. Moestopo No. 47 Surabaya, 60132 Indonesia. Email: jesslyn.jordana-2020@fkg.unair.ac.id

INTRODUCTION

Irrigation is an essential step in root canal treatment (RCT) that aims to remove pulp tissue anderadicate microorganisms in the root canal.[1] Sodium Hypochlorite (NaOCl) is commonly used as an endodontic irrigant in clinical treatment as it has tissue dissolution and antibacterial capacity. The effectiveness of irrigation depends on both the irrigants' ability to dissolve tissue and the mechanical flushing action to remove material from the canal. Irrigants must be brought into direct contact with the entire canal area and especially with the apical portions of narrow root canals for optimal irrigation. However, cleaning the apical area with its morphological variations is complicated since the irrigants cannot easily reach that area.[2] Furthermore, an amorphous layer of organic and inorganic material known as the smear layer may form on theroot canal walls after pulp extirpation and instrumentation, preventing the diffusion of irrigants,and resulting in RCT failure.[2,3]

There are several ways to transfer irrigants into the root canal, one of which is conventional irrigation with a needle syringe. However, due to the complexity of the root canal, there is a higher risk of pulp tissue remnants, bacteria, and smear layer retained in the root canalafter using conventional irrigation method, regardless of instrumentation size and high volume of NaOCl. This condition often results in the RCT failure and recurrence of the disease.[2,4,5] Theprevalence rate of RCT failure due to inadequate cleaning of existing irritants in the pulp and other microbial-related factors ranges up to 10.4% and 3.6%, respectively.[6] For this reason, a number of additional approaches have been developed to improve the flushing action of irrigants, including laser-activated irrigation.[7]

Laser-activated irrigation of root canals has been widely applied in clinical practices dueto its superior antimicrobial effect compare to conventional irrigation.[3] One of which is shockwave enhanced emission of photoacoustic streaming (SWEEPS) that utilized Er: YAG laser. SWEEPS uses ultrashort micropulses (25 msec) of low energy (20 mJ) to generate a series of bubbles delivered in the liquid. The first micropulse generates the main bubble and the second micropulse timed to appear such that it collapses the main bubble, amplifying pressure waves in the liquid and causing powerful photodynamic streaming that can improve root canal cleaning and disinfection.[8]

The benefits of SWEEPS over conventional irrigation in root canal cleaning and disinfection has been reported in several literatures. However, some literatures show conflicting results regarding the benefits of SWEEPS. Therefore, this study aims to reviewthe available evidence to assess the benefits of SWEEPS over conventional irrigation in removing smear layer, debris, pulp tissues, and bacteria in the root canal.

METHODS

Scoping reviews are a type of studies that systematically maps evidence on a specific subject matter, identifying key concepts, theories, sources of evidence, and research.[9] This scoping review was conducted using Arksey and O'Malley methodology which consists of five steps: (1) identifying the research question, (2) identifying relevant studies, (3) selecting studies, (4) extracting data, (5) collating, summarizing and reporting the results.

Scoping review question

The topic of interest was the use of SWEEPS in root canal irrigation. The scoping review alongside the search strategy was driven by the following broad question: what benefits do SWEEPS provide over conventional irrigation in the removal of smear layer, debris, pulp tissue remnants, and bacteria? The question encompasses the use of SWEEPS in root canal irrigation and the comparison between SWEEPS and conventional irrigation as root canal irrigation method.

Inclusion criteria

Experimental studies written in English only, which assessed the benefits of SWEEPS over conventional irrigation within these parameters: removal of smear layer, debris,pulp tissue remnants, and bacteria, were all included in the review.

Exclusion criteria

Studies excluded from the review were duplication studies, studies other than experimental studies (literature review, letters to editors, opinions, conference abstracts, dissertations, theses, case control, case report, case series, cohort, cross sectional, ecological correlation studies), studies with irrelevant title and abstract, did not asses the benefits of SWEEPS over conventional irrigation within these parameters: removal of smear layer, debris, pulp tissue remnants, bacteria, and inaccessible full text.

Search strategy

The systematic search of literature was conducted on four electronic databases, including Pubmed, ScienceDirect, EBSCOhost, and ProQuest. The keywords used were SWEEPS and root canal irrigation. Article searches were done from 1st August to 1st October 2022.

Study selection

After a preliminary evaluation of the first 50 articles in alphabetical order, two reviewers (JJ and JF) became acquainted with the inclusion and exclusion criteria. The selection of the studies was discussed together to ensure that there was a certain agreement between two reviewers in the study selection. The two reviewers then independently screened all titles and abstracts and excluded studies for their irrelevance to the review based on the inclusion and exclusion criteria. If there is any disagreement between the two reviewers in thestudy selection process, the third reviewer (JN) will be asked to participate in the discussion toresolve the disagreement. MyBib software was used to import and manage the references.

RESULTS

A total of 833 articles were initially retrieved from systemic search of literature. Figure 1 shows the preferred reporting items for systematic reviews and meta-analysis (PRISMA) flow chart of the scoping review study selection process. There were 827 studies left for screening after the removal of 6 duplicates. Two reviewers (JJ and JF) independently selected 10 articles for the assessment of full-text eligibility after reviewing the title and abstracts. After reading the full text, reviewer 1 (JJ) and 2 (JF) selected 5 and 6 articles respectively to be included in the scoping review. The disagreement was consulted with the third reviewer (JN) and a final of 6 articles were included in the scoping review.

Table 1 shows the data extracted from 6 articles included in the scoping review. Out of6 articles, 4 articles suggested that SWEEPS could increase the removal of smear layer, debris, pulp tissues, and bacteria in the root canal compared to conventional irrigation. However, 2 articles found contradictory results, in which SWEEPS and conventional irrigation had similar outcomes in terms of penetration depth and could not completely eradicate biofilm of the root canal.

DISCUSSION

SWEEPS laser-assisted irrigation generates photon-induced photoacoustic streaming of irrigants throughout the complex three-dimensional root canal system by using a special type of Er:YAG laser with extremely short laser pulses.[12] In constrained places like root canals, thesynchronized super short Er:YAG laser-pulse delivery causes a quick creation of collapsed bubbles. A second pulse is introduced into the liquid just as the first laser-induced cavitation bubble begins to collapse, creating a second cavitation bubble. The growth of the second cavitation bubble accelerates the collapse of the first cavitation bubble, leading to a violent collapse, during which shock waves are emitted. Furthermore, shock waves are also generatedby collapsing secondary cavitation bubbles that naturally grow throughout the whole length of the canal during laser-induced irrigation. The secondary

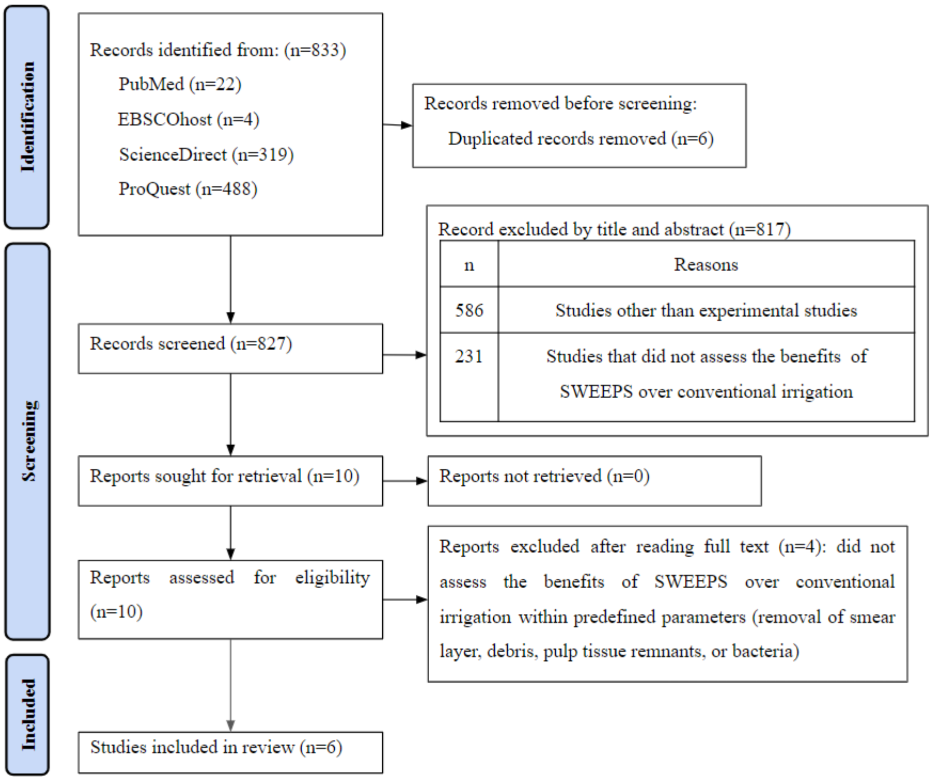

Figure 1. PRISMA flow diagram for the scoping review study selection process.

Table 1. Benefits of SWEEPS over conventional irrigation in removing smear layer, debris, pulp tissues, or bacteria

Author	Study design	Parameter	Result
Vatanpour, Sohrab & Sajjad (2022)[2]	RCT	Removal of smearlayer and debris	SWEEPS significantly removed smear layer and debris, better than conventional irrigation($p<0.001$).
Bago et al.(2022)[8]	RCT	Removal of pulp tissue	SWEEPS was the most successful in removing remnants of pulp tissue ($p=0.001$, 0.002). In the middle third, SWEEPS showed superior efficacy to conventional irrigation ($p<0.05$). In the apicalthird, SWEEPS was the most efficient method in removing pulp tissue ($p=0.002$).
Lei et al. (2022)[5]	RCT	Removal of Enterococcus faecalis in infected root canal	After root canal irrigation with SWEEPS, the viable count of E. faecalis was significantly reduced($p<0.05$). SWEEPS can enhance the effect of low-concentration NaOCl while ensuring the antimicrobial effect.
Kosarieh et al. (2021)[4]	RCT	Penetration depth of irrigants (simulated using two differentdyes: indocyaninegreen solution (ICG) and methylene blue solution)	SWEEPS and the conventional irrigation have a similar outcome in terms of dye penetration. In the coronal, middle, and apical area, the difference between conventional irrigation and SWEEPS in Indocyanine green dye penetration was not significant ($p>0.05$). However, there is ahigher penetration of methylene blue dye with SWEEPS compared to conventional irrigation, especially in the middle area.
Kumar, Teoh & Walsh (2022)[10]	RCT	Removal of biofilm	Both SWEEPS and conventional irrigation methods could not completely eradicate biofilm from the most confined regions of the root canal system.
Widbiller et al. (2021)[11]	Non-RCT	Removal of hard tissue debris	SWEEPS proved to be more superior than conventional irrigation regarding the removal of debris, which persisted particularly in the apical third of the root canal in the control group ($p = 0.000$).

cavitation bubbles, in contrast to the primary cavitation bubbles, are in close proximity to canal walls during their collapses, resulting in shear flows that can remove debris from the surface. The shock waves are still propagating at supersonic speeds when they reach the smear layer because of their proximity to the canal walls, which might further enhance the cleaning process.[13]

Based on 6 articles included in the review, 4 articles proved that SWEEPS could increase the removal of smear layer, debris, pulp tissues, and bacteria in the root canal comparedto conventional irrigation.[2,5,8,11] Bago et al.[8] stated that in the SWEEPS group, all samples were found completely free of remaining pulp tissues in all parts of the canal. This result is in accordance with Widbiller et al.[11] research, in which SWEEPS was more successful in removing hard tissue debris in the apical third.

In cases of fractured files, SWEEPS was also proven to enhance the cleaning of apical areadespite the presence of fractured instruments. The benefits of SWEEPS is due to high shear stress applied on the walls of the root canal that is produced by collapsing of bubbles in the irrigants. The irrigants can proceed 2-3 mm beyond the ultrasonic tip, providing a cleaner area beyond fractured files, because fractured files often have 2-3 mm lengths. Furthermore, the effect of SWEEPS is not influenced by the root canal's curvature because it is muchlarger than the usual streaming length scale. There is also no obligation to place the laser tip tothe apical area because SWEEPS works by generating pulse and stream, hence keeping the SWEEPS tip in the pulp chamber is sufficient to do its job.[2]

Another benefit of SWEEPS mentioned in Lei et al. [5] is that in addition to its enhancedcleaning effect, SWEEPS can reduce the concentration of NaOCl to a safer level, thus minimizing the potential risk of tissue damage from high concentrations of NaOCl. The studyshowed that SWEEPS with low concentration NaOCl demonstrated a satisfactory capacity for root canal decontamination by increasing the chlorine content in irrigants. In addition, SWEEPS can also increase the contact between bacteria and chlorine by photomechanical, photoacoustic, and activation effect, promoting mechanical scouring of the root canal wall and infiltration of irrigants into dentin tubules.

The remaining 2 articles showed contradictory results.[4,10] SWEEPS can improve root canal cleaning by increasing penetration of irrigants into the main and lateral canal in the apical section. However, research by Kosarieh et al. [4] showed that there was no significant difference between conventional irrigation and the SWEEPS technique in increasing penetration depth ofirrigants into the canal. This might be due to the decreased number of dentinal tubules from the coronal to the apical portion, thus justifying the lower penetration depth from the coronal to the apical portion.[14] The tip that is placed deeper and constantly moved in the pulp chamber tends to make the penetration of the irrigation solution better and can reach deeper parts of the main and lateral canals.[4]

Another contradictory result is also stated in the study conducted by Kumar, Teoh, and Walsh[10] which stated neither SWEEPS nor conventional irrigation could completely eradicate biofilms from the most confined areas of the root canal system. The failure to prove SWEEPS' benefits in increasing the removal of biofilm from the root canal is due to the sample used in the study. The study used mesial roots of the permanent mandibular first and second molars with very complex anatomy of root canal and without intact crown of the tooth.The absence of a crown caused decreased volume of irrigation fluid and loss of reservoir function, making the results of this study cannot be compared with other similar studies. Although the Er:YAG laser with the SWEEPS technique could not completely clean the biofilm in the root canal, the SWEEPS technique still showed better canal and isthmus cleanness than the conventional syringe irrigation method.

In line with the scoping review question and objectives, we limited our search to studiesthat assessed the benefits of SWEEPS over conventional irrigation within these parameters: removal of smear layer, debris, pulp tissue remnants, and bacteria. Confining the review to studies written in English only and excluding grey literature such as conference proceedings, theses, and dissertations, are other limitations which may have caused theomission of some relevant studies. In addition, studies included in this review were all in vitrostudies that could not completely imitate the clinical situation.

Within the limitations of this study, we concluded that SWEEPS offers more benefits over conventional irrigation since it can improve the removal of smear layer, debris, pulp tissues, and bacteria in the root canal. SWEEPS can improve root canal cleaning and disinfection by causing powerful photodynamic streaming and increasing penetration ofirrigants into the main and lateral canal in the apical section. In future studies, the benefits of SWEEPS over conventional irrigation should be investigated using an in vivo experimental design to provide a more reliable approach for root canal irrigation in clinical situations.

REFERENCES

1. Widyastuti NH, Nurhabibah G. Nonvital Root Canal Treatment of Necrotic Maxillary Left Lateral Incisor: A Case Report. Proceeding ISETH (International Summit on Science, Technology, and Humanity). 2021.
2. Vatanpour M, Toursavadkouhi S, Sajjad S. Comparison of three irrigation methods: SWEEPS, ultrasonic, and traditional irrigation, in smear layer and debris removal abilities in the root canal, beyond the fractured instrument. Photodiagnosis and Photodyn Ther. 2022; 37:102707.
3. Tong J, Liu L, Du J, Gao Y, Song D, Huang D. Effect of photon-induced photoacoustic streaming and shock-wave enhanced emission photoacoustic streaming technique on the removal of the smear layer after root canal preparation in curved root canals. Journal of Dental Sciences. 2022.
4. Kosarieh E, Bolhari B, Sanjari Pirayvatlou S, Kharazifard MJ, Sattari Khavas S, Jafarnia S, et al. Effect of Er:YAG laser irradiation using SWEEPS and PIPS technique on dye penetration depth after root canal preparation. Photodiagnosis and Photodyn Ther. 2021; 33:102136.

5. Lei L, Wang F, Wang Y, Li Y, Huang X. Laser Activated Irrigation with SWEEPS Modality Reduces Concentration of Sodium Hypochlorite in Root Canal Irrigation. Photodiagnosis and Photodyn Ther. 2022; 102873.
6. Mustafa M, Almuhaiza M, Alamri HM, Abdulwahed A, Alghomlas ZI, Alothman TA, Alhajri FF. Evaluation of the causes of failure of root canal treatment among patients in the City of Al-Kharj, Saudi Arabia. Nigerian Journal of Clinical Practice. 2021.
7. Jezeršek M, Lukač N, Lukač M. Measurement of Simulated Debris Removal Rates in an Artificial Root Canal to Optimize Laser-Activated Irrigation Parameters. Lasers in Surgery and Medicine. 2020; 53(3):411–7.
8. Bago I, Batelja-Vuletić L, Tarle A, Sesar A, Anić I. Novel laser activated photoacoustic streaming for removing pulp remnants from round root canals after single file reciprocating instrumentation. Photodyn Ther. 2022.
9. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Annals of Internal Medicine. 2018.
10. Kumar K, Teoh Y-Y, Walsh LJ. Root canal cleaning in roots with complex canals usingagitated irrigation fluids. Australian Endodontic Journal. The Journal of the Australian Society of Endodontology. 2022.
11. Widbiller M, Keim L, Schlichting R, Striegl B, Hiller K-A, Jungbauer R, et al. Debris Removal by Activation of Endodontic Irrigants in Complex Root Canal Systems: A Standardized In-Vitro-Study. Applied Sciences. 2021; 11(16):7331.
12. Vishwaja U, Panthangi S, Lakshmi Charan Reddy C, Basavaiah Babu M, Podili S. Novel sweeps technology in endodontics — A review. IP Indian Journal of Conservative and Endodontics. 2021; 6(3):134–42.
13. Lukač N, Jezeršek M. Amplification of pressure waves in laser-assisted endodontics with synchronized delivery of Er:YAG laser pulses. Lasers in Medical Science. 2018.
14. Lo Giudice G, Cutroneo G, Centofanti A, Artemisia A, Bramanti E, Militi A, et al. Dentin Morphology of Root Canal Surface: A Quantitative Evaluation Based on a Scanning Electronic Microscopy Study. BioMed Research International. 2015.